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NASA CR-144946-1

Part 1 of 4

A COMPILATION OF SPACECRAFT LOADS DATA  
FROM  
FOUR TITAN CENTAUR LAUNCH VEHICLE FLIGHTS

VOLUME III: SHOCK SPECTRA OF TRANSIENTS

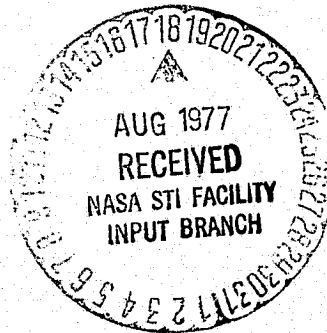
Compiled by: George Kachadourian

(NASA-CR-144946-Pt-1) A COMPILATION OF  
SPACECRAFT LOADS DATA FROM FOUR TITAN  
CENTAUR LAUNCH VEHICLE FLIGHTS. VOLUME 3,  
PART 1: SHOCK SPECTRA OF TRANSIENTS  
(General Electric Co.) 55 p HC A04/MF A01

N77-28186

Unclass  
42480

G3/15



Prepared under Contract No. NAS1-9100 by  
GENERAL ELECTRIC COMPANY  
Viking Project Support Services  
Hampton, Va. 23666

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

January 1977



1. Report No. NASA CR-144946-1		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle A COMPILATION OF SPACECRAFT LOADS DATA FROM FOUR TITAN CENTAUR LAUNCH VEHICLE FLIGHTS VOLUME III: SHOCK SPECTRA OF TRANSIENTS				5. Report Date January 1977	
				6. Performing Organization Code	
7. Author(s) George Kachadourian				8. Performing Organization Report No.	
				10. Work Unit No.	
9. Performing Organization Name and Address General Electric Company Viking Project Support Services 17 Research Road, Hampton, VA. 23666				11. Contract or Grant No. NAS1-9100	
				13. Type of Report and Period Covered Contractor Report	
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Langley Research Center, Hampton, VA. 23665				14. Sponsoring Agency Code	
15. Supplementary Notes This report is a compilation of shock spectra data processed by the Langley Research Center Analysis and Computation Division with assistance from the Systems Engineering Division and under the direction of the Viking Project Office.					
16. Abstract  The payloads carried by the first four Titan Centaur Launch Vehicle flights were a Viking Dynamic Simulator, the Helios A Spacecraft and the two Viking Spacecraft. Dynamic loads data were gathered by the NASA Viking Project Office from these four flights for applications to the Viking Spacecraft. This volume contains time histories and shock spectra of vibration and acceleration measurements made on TC-1, TC-4 and TC-3 during all launch and staging events where a measurable response was obtained. Summary plots are also presented. Comparisons to Viking Program Mid-Frequency Sine Test requirements are made.					
17. Key Words (Suggested by Author(s)) Viking Spacecraft, Titan Centaur, Transient Vibration Shock Spectra Sine Sweep Test Criteria				18. Distribution Statement  Unclassified	
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages	
				22. Price*	

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2.	TC-1 Data (Viking Dynamic Simulator)	1.0
3.	TC-4 Data (Viking A Spacecraft)	2.0
4.	TC-3 Data (Viking B Spacecraft)	3.0

Ref. 1. Synder, R. E., Trummel, M., Wada, B.K. and Pohlen, J. C.,  
Specification and Correlation of the Sine Vibration Environment  
for Viking '75., SAE Paper No. 740814, presented at the  
National Aerospace Engineering and Manufacturing Meeting,  
San Diego, California, Oct. 1-3, 1974.

Ref. 2 Kachadourian, George, A Summary of Spacecraft Loads Data  
From Four Titan Centaur Launch Vehicle Flights.  
NASA CR -2645, 1977.

### Notations Used in Volume III

Bus -	Major structural assembly of Viking Orbiter - See Figure 3.1
FBR -	Forward Bearing Reaction, support between Centaur and Shroud
Max Q -	Period of launch flight of maximum dynamic pressure.
PSD -	Power spectral density, vibration, $g^2$ /Hertz
VDS -	Viking Dynamic Simulator, TC-1 payload
VLC -	Viking Lander Capsule
VLCA -	Viking Lander Capsule Adapter
VO -	Viking Orbiter
VS/C -	Viking Spacecraft
V-S/C-A -	Viking Spacecraft Adapter
TC-1 -	The Titan Centaur Launch Vehicle Number 1
TC-2 -	The Titan Centaur Launch Vehicle Number 2, Helios Spacecraft
TC-3 -	The Titan Centaur Launch Vehicle Number 3, Second Viking Spacecraft launch.
TC-4 -	The Titan Centaur Launch Vehicle Number 4, First Viking Spacecraft launch.
FA -	Flight Acceptance Test
TA -	Type Approval Test
SRM -	Solid Rocket Motor - Titan Stage 0
MES -	Main Engine Start - Centaur
MECO -	Main Engine Cut Off - Centaur

## Application of Shock Spectrum Data to Mid-Frequency Sine Test Criteria

Mid-Frequency sine testing as defined in the Viking Program is sine sweep testing in the frequency range between 5 and 200 Hertz. Mid-frequency sine testing was performed both at the system level and component level.

The mid-frequency sine test procedures were designed to reproduce the transient vibrations caused by the Launch Vehicle flight and staging events as to acceleration levels and frequency with an accepted overtest as to total number of cycles. The basis for the test requirements is summarized in Figure 0.1, from Reference 1. As detailed in Reference 1, in the design phase of the Viking Program applicable analytical and flight data of Launch Vehicle transients were compiled in the form of acceleration shock spectra. Margins were put on this data, as indicated in Figure 0.1 and an envelope drawn. This envelope was then converted to the Flight Acceptance (FA) sine test level, Figure 0.2, which would result in the same response levels, with an assumed dynamic amplification (Q). In Reference 1 the shock spectra were obtained with an assumed  $Q = 20$  and the sine test level was consequently also based on  $Q = 20$ .

The Viking Mid-Frequency sine test requirements were further refined with the imposition of response load limit criteria. The resulting test input levels are summarized in Figure 0.3 through 0.7. These input levels include a multiplying factor of X10 to make the data directly comparable to flight test shock spectra with  $Q = 10$ .

This volume presents shock spectra performed at LRC on data from TC-1, TC-4 and TC-3. Section 1 contains summary plots with comparisons to the Mid-Frequency sine test as discussed above. Section 2, 3 and 4 contain the shock spectra from TC-1, TC-4 and TC-3 respectively. Comparison between flight measurements and test criteria are developed and discussed in Reference 2.

### Explanation of Figure Headings

- |             |   |
|-------------|---|
| System -    | refers to system test of Viking Lander Capsule - (VLC) or Viking Orbiter - (VO)                       |
| Location -  | refers to location of the measurement; VO Bus is also used to denote VLC input during VLC system test |
| Direction - | refers to direction of measurement and test.  |

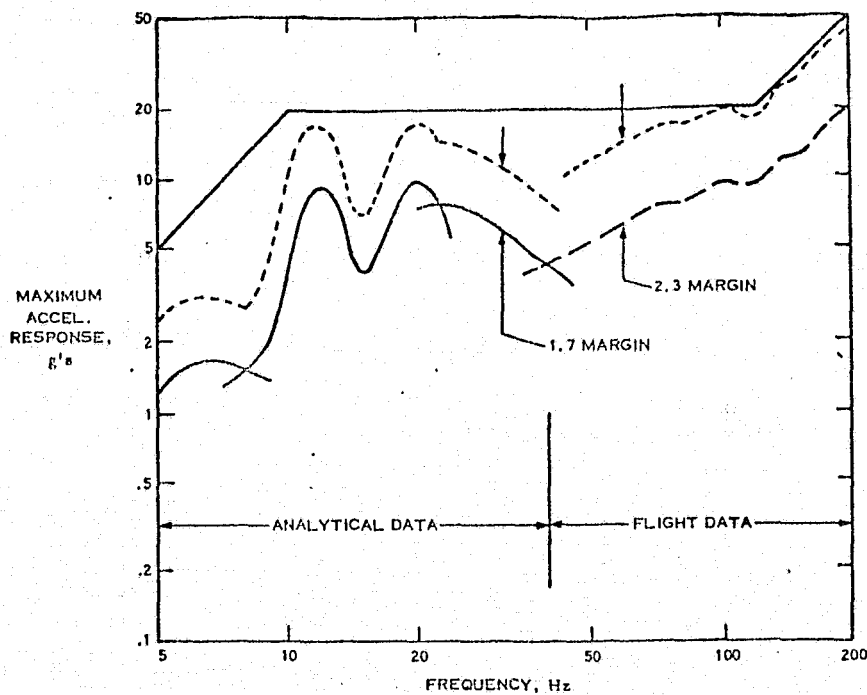


Figure 0.1 Determination of Mid Frequency Test Levels

Figure 0.1 Determination of Mid Frequency Test Levels

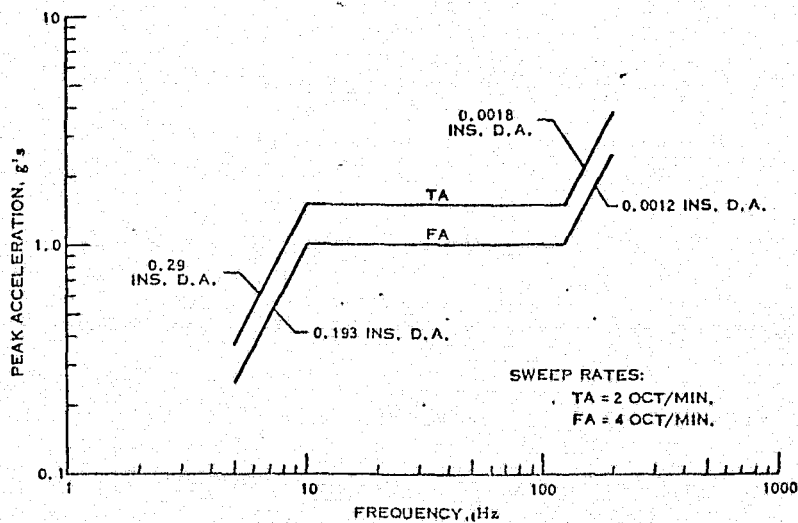
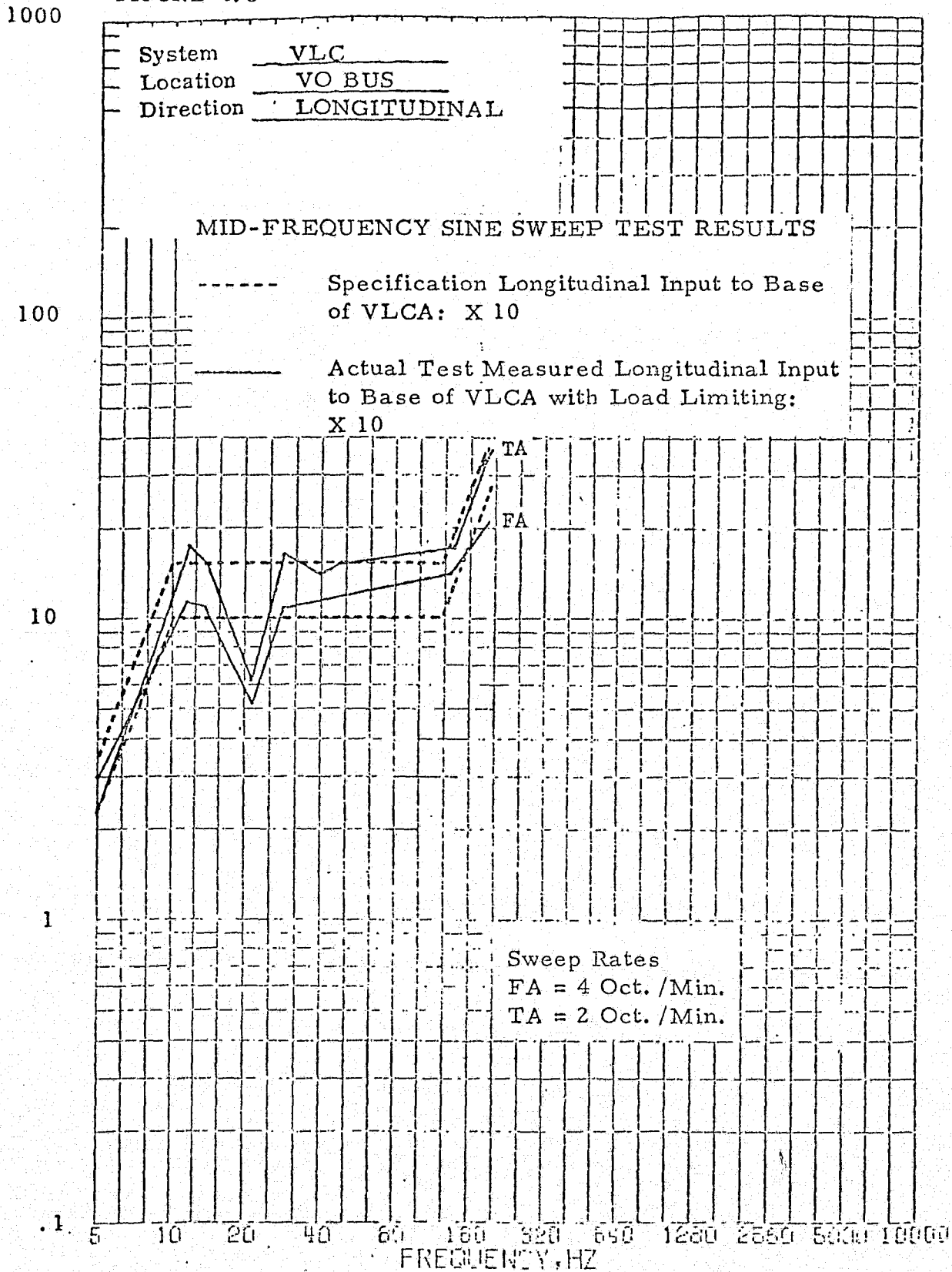


Figure 0.2 Mid Frequency Test Levels, Viking Program

# SHOCK SPECTRUM

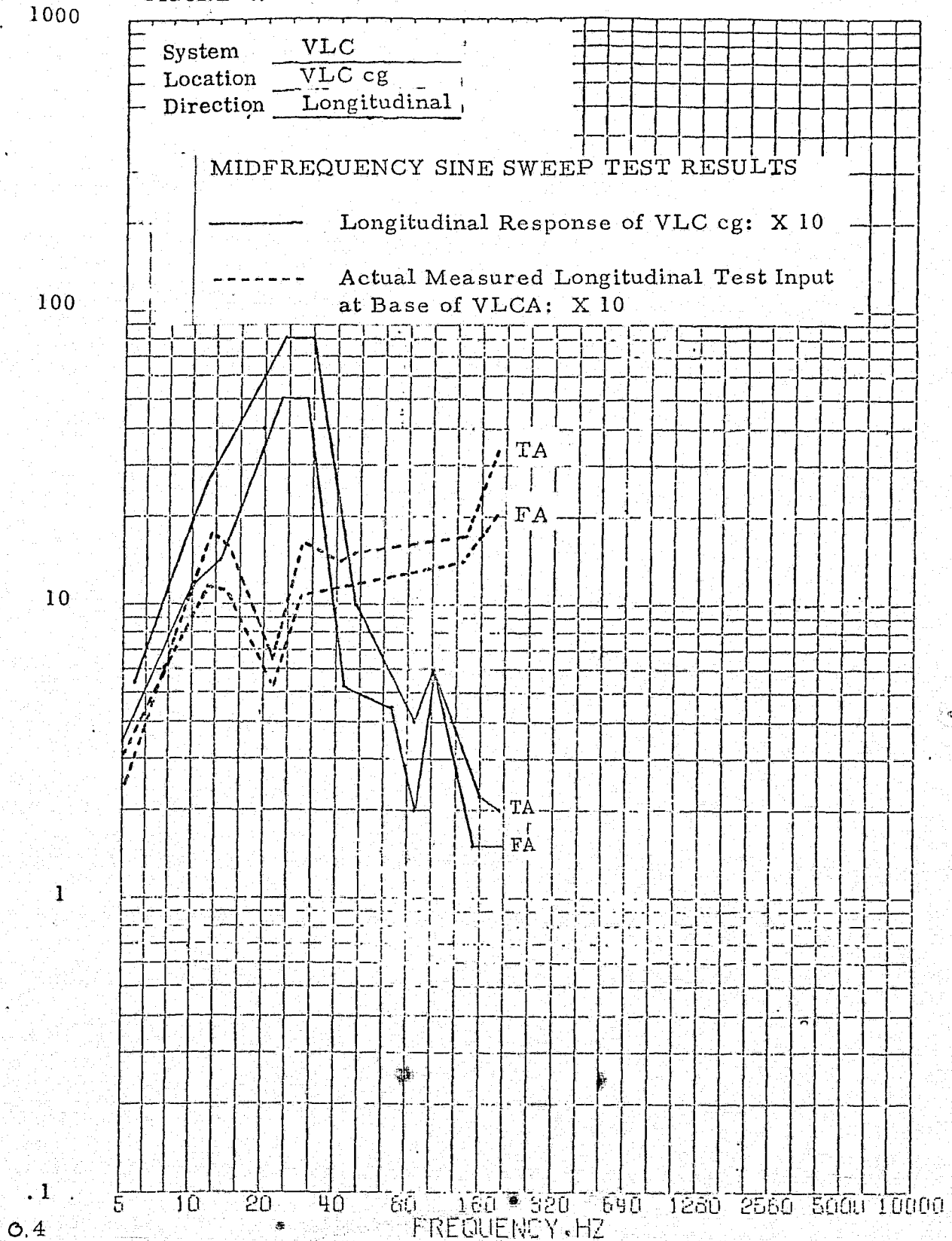
FIGURE 0.3



(2)

# SHOCK SPECTRUM

FIGURE 0.4



(3)

# SHOCK SPECTRUM

FIGURE 0.5

1000

System	VLC
Location	VLC cg.
Direction	Lateral

## MIDFREQUENCY SINE SWEEP TEST RESULTS

100

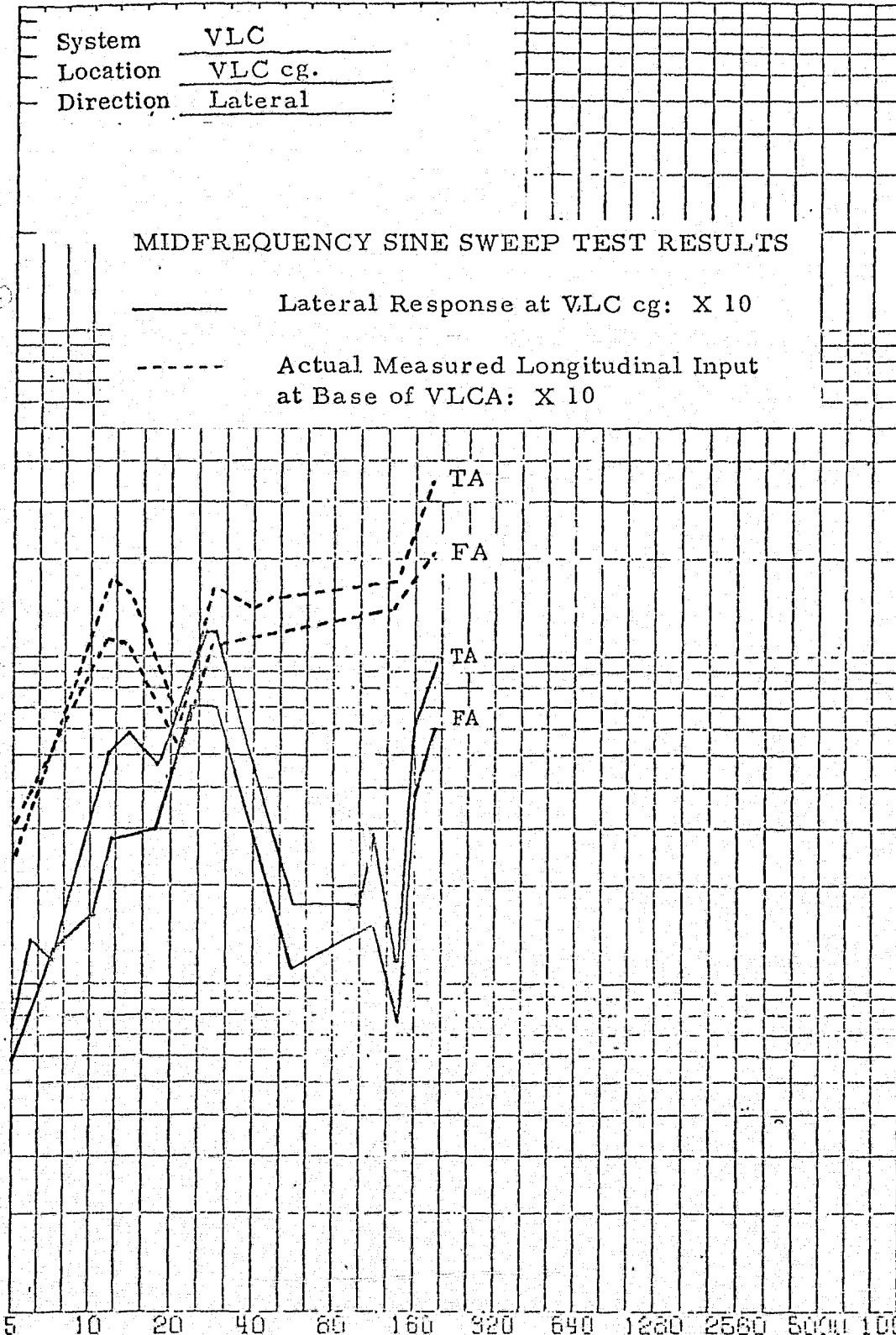
- Lateral Response at VLC cg: X 10
- Actual Measured Longitudinal Input at Base of VLCA: X 10

10

1

.1 5 10 20 40 60 160 320 640 1280 2560 5000 10000 0.5

FREQUENCY, HZ

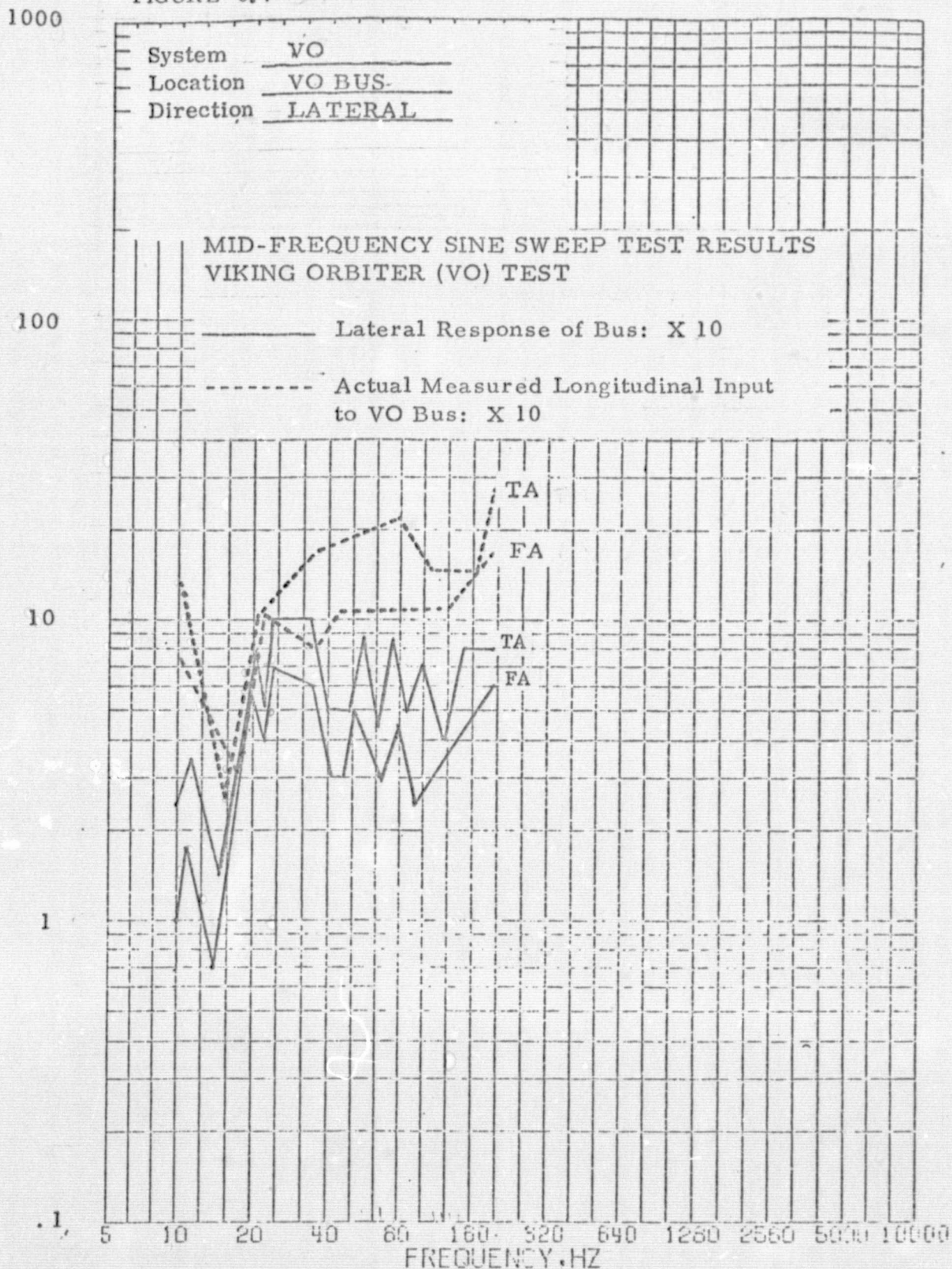




5

# SHOCK SPECTRUM

FIGURE 0.7



## VOLUME 3 SECTION 1

## SUMMARY PLOTS

## SHOCK SPECTRA OF TRANSIENT EVENTS

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## Discussion of Contents: Summary Shock Spectrum Plots

The summary shock spectra in this section are compared to the Viking Mid-Frequency sine test levels reviewed at the beginning of this Volume. The POGO and FLMN oscillations refer to the longitudinal oscillations at the Viking Orbiter (VO) Bus during Titan Stage I burn: POGO implies a limit-cycle feedback coupling of the propulsion system and the Launch Vehicle longitudinal structural mode; FLMN refers to the First Longitudinal Mode response as a "Noise" response driven by thruster roughness. All shock spectra used in the comparison were obtained with  $Q = 10$ . The shock spectra were divided into four groups, longitudinal and lateral of the Orbiter Bus and at the Viking Lander Capsule (VLC) center of gravity. Table 1.1 list the measurements used in each of the four groups.

Table 1.1 Grouping of Measurements in Summary Plots

Group	Location	Direction	Sensors	
			TC-1	TC-4 & 3
1	VO Bus	Longitudinal	CY2010 CY2020 CY2030 CY2040	CY1820 CY1840 CY1850 ZDDB
2	VO Bus	Lateral	CY2050 CY2060 CY2070	CY1830
3	VLC-CG	Longitudinal	-	ZDDL
4	VLC-CG	Lateral	-	XDDL YDDL

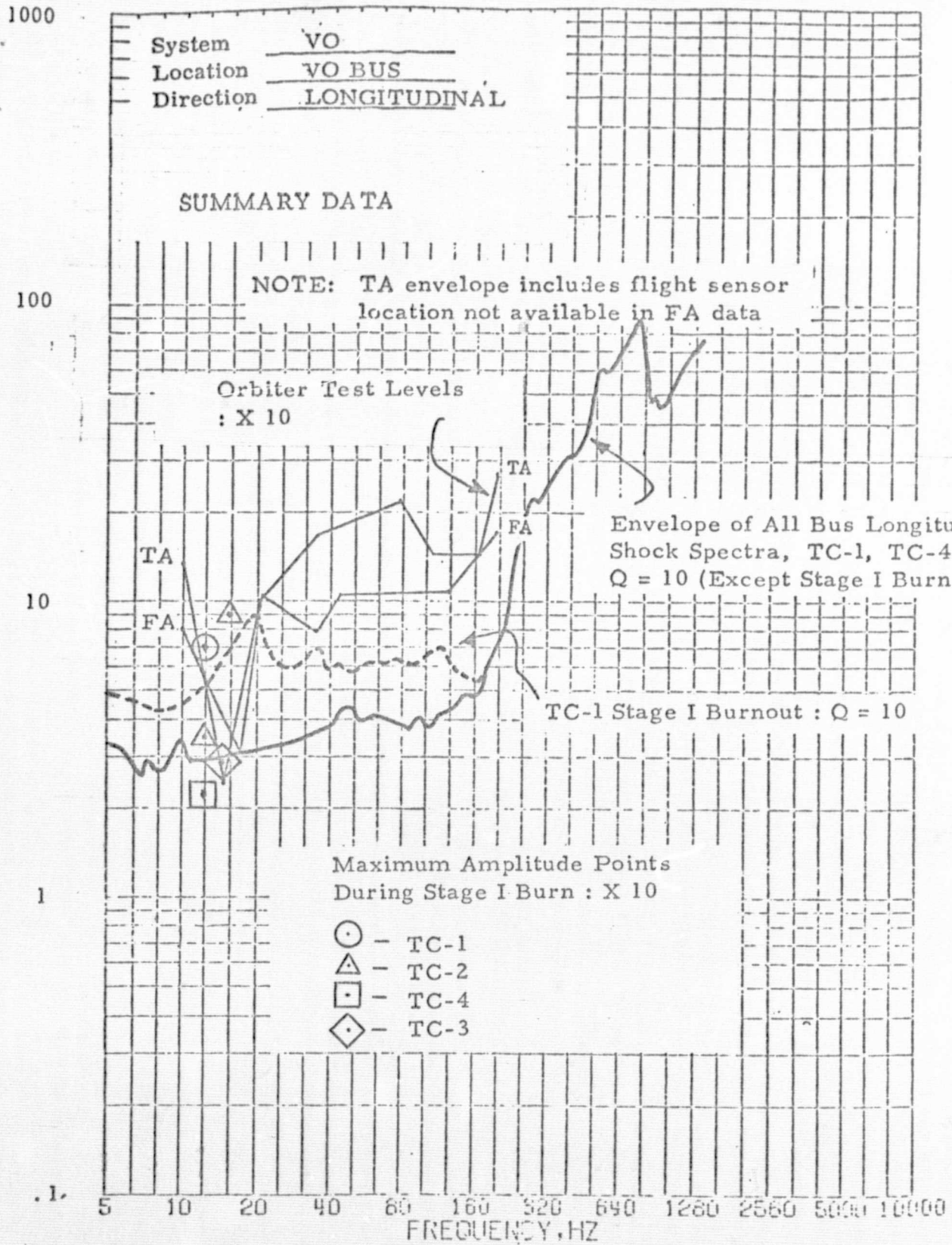
ZDDB is the acceleration obtained from the instantaneous averaging of the three longitudinal vibration sensors CY1820, CY1840 and CY1850. ZDDL, XDDL & YDDL are the cg accelerations of the VLC obtained from the Viking Lander Capsule Adapter (VLCA) strain data assuming a rigid Lander.

(4)

# SHOCK SPECTRUM

FIGURE 1.1

Q = 10



(5)

# SHOCK SPECTRUM

FIGURE 1.2

Q = 10

1000

System	<u>VO</u>
Location	<u>VO BUS</u>
Direction	<u>LATERAL</u>

## SUMMARY DATA

100

Envelope of all VO Bus Lateral  
Shock Spectra, TC-1, TC-4 & TC-3

Orbiter Test Levels

10

TA

FA

1

Maximum Lateral Amplitude  
During Stage 1 Burn, VO Bus : X 10

- - TC-1
- △ - TC-2
- - TC-4
- ◇ - TC-3

----- Max Lateral Amplitude During  
Centaur First Burn, VO Bus : X 10

.1

5 10 20 40 80 160 320 640 1280 2560 5000 10000  
FREQUENCY, HZ



# SHOCK SPECTRUM

Q = 10

FIGURE 1.3

1000

System	VLC
Location	VO BUS
Direction	LONGITUDINAL

## SUMMARY DATA

100

VLC Test Levels : X 10

TA

FA

Envelope of All Bus  
Longitudinal Shock Spectra  
TC-1, TC-4 & TC-3 : Q = 10  
(Except TC-1 Stage I Burn Out)

10

TC-1 Stage I Burn Out : Q = 10

Maximum Amplitude Points  
During Stage I Burn : X 10

- — TC-1
- △ — TC-2
- — TC-4
- ◇ — TC-3

1

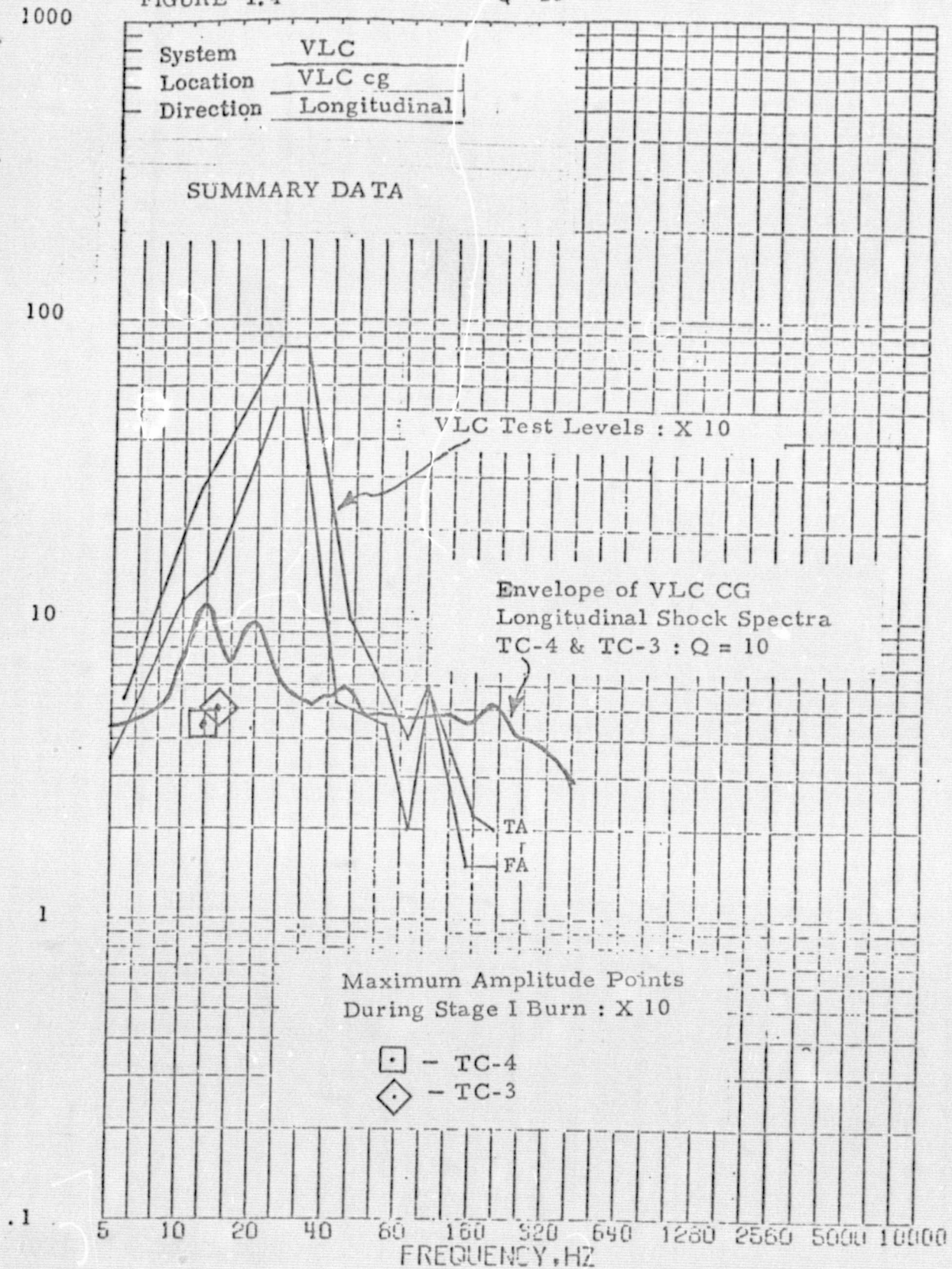
.1

5 10 20 40 60 160 320 640 1280 2560 5000 10000  
FREQUENCY .HZ

2

# SHOCK SPECTRUM Q = 10

FIGURE 1.4

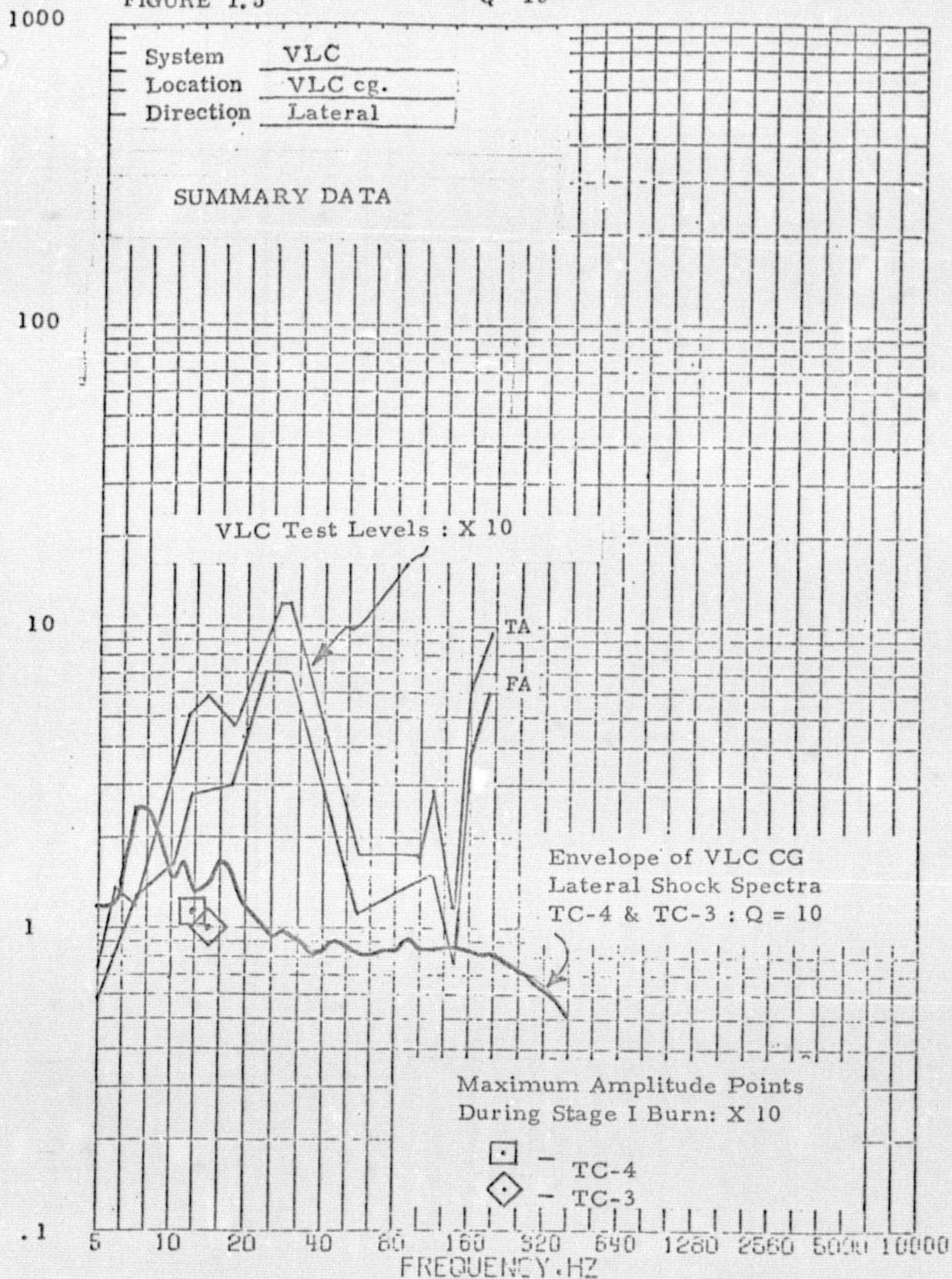




(3)

# SHOCK SPECTRUM Q = 10

FIGURE 1.5





4

# SHOCK SPECTRUM Q = 10

FIGURE 1.6

1000

System	VO
Location	VO BUS
Direction	LONGITUDINAL
Event	LIFTOFF
Time	

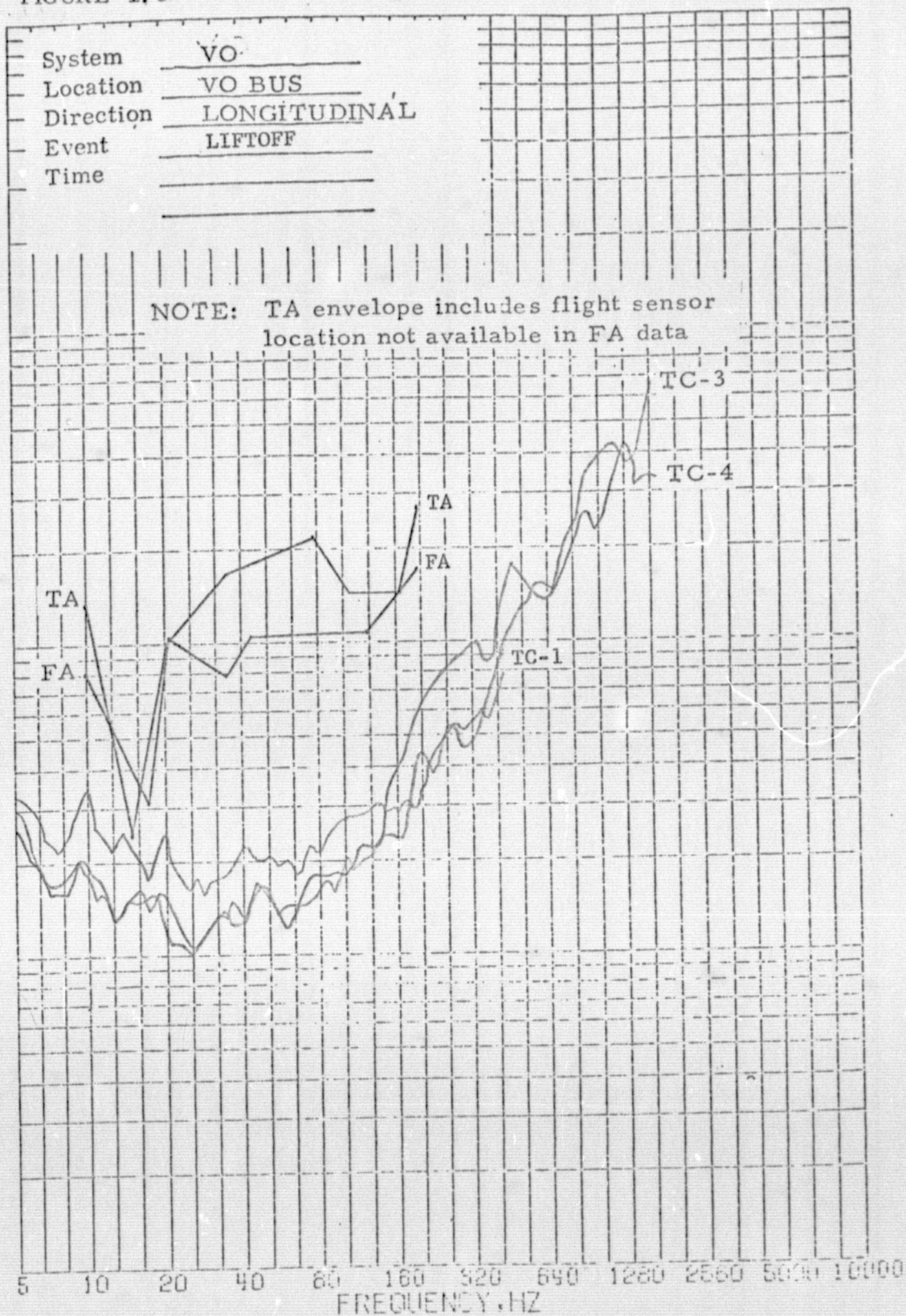
100

NOTE: TA envelope includes flight sensor  
location not available in FA data

10

1

.1

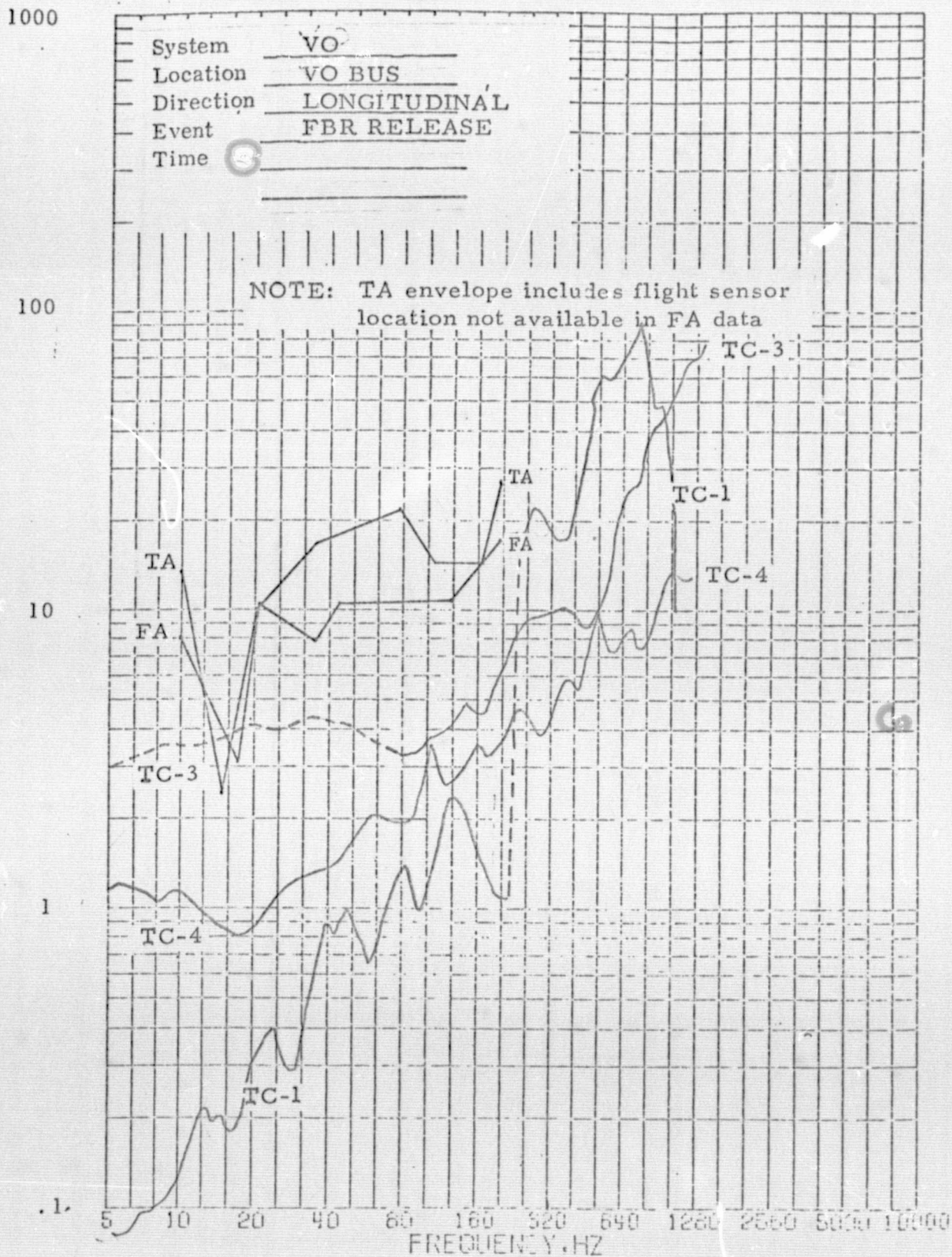


4

# SHOCK SPECTRUM

Q = 10

FIGURE 1.7





4

# SHOCK SPECTRUM

Q = 10

FIGURE 1.8

1000

System	VO
Location	VO BUS
Direction	LONGITUDINAL
Event	STAGE 1 IGNITION
Time	

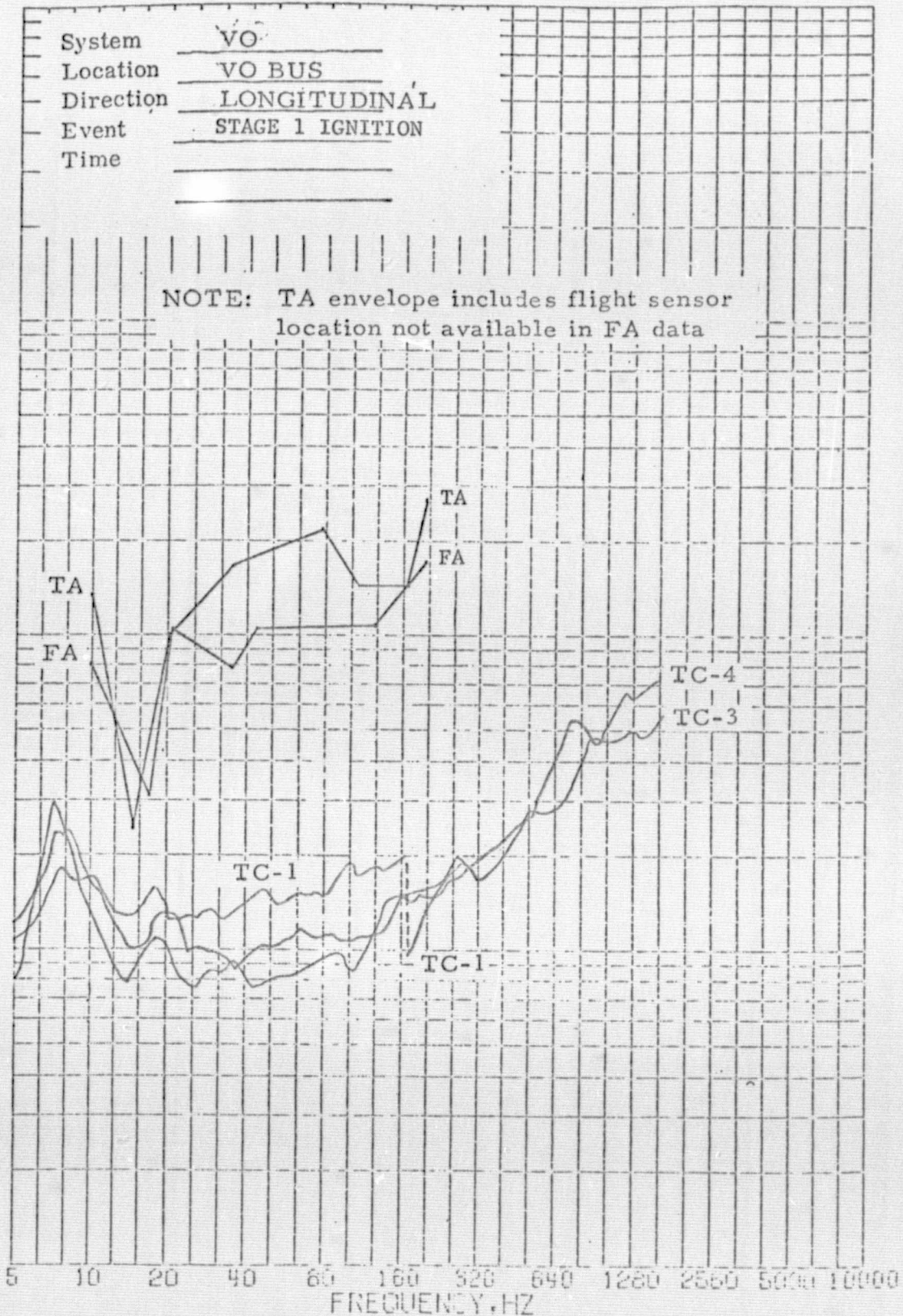
100

NOTE: TA envelope includes flight sensor  
location not available in FA data

10

1

.1



4

# SHOCK SPECTRUM

Q = 10

FIGURE 1.9

1000

System	VO
Location	VO BUS
Direction	LONGITUDINAL
Event	STAGE 1 SHUTDOWN/ STAGE 2 IGNITION
Time	

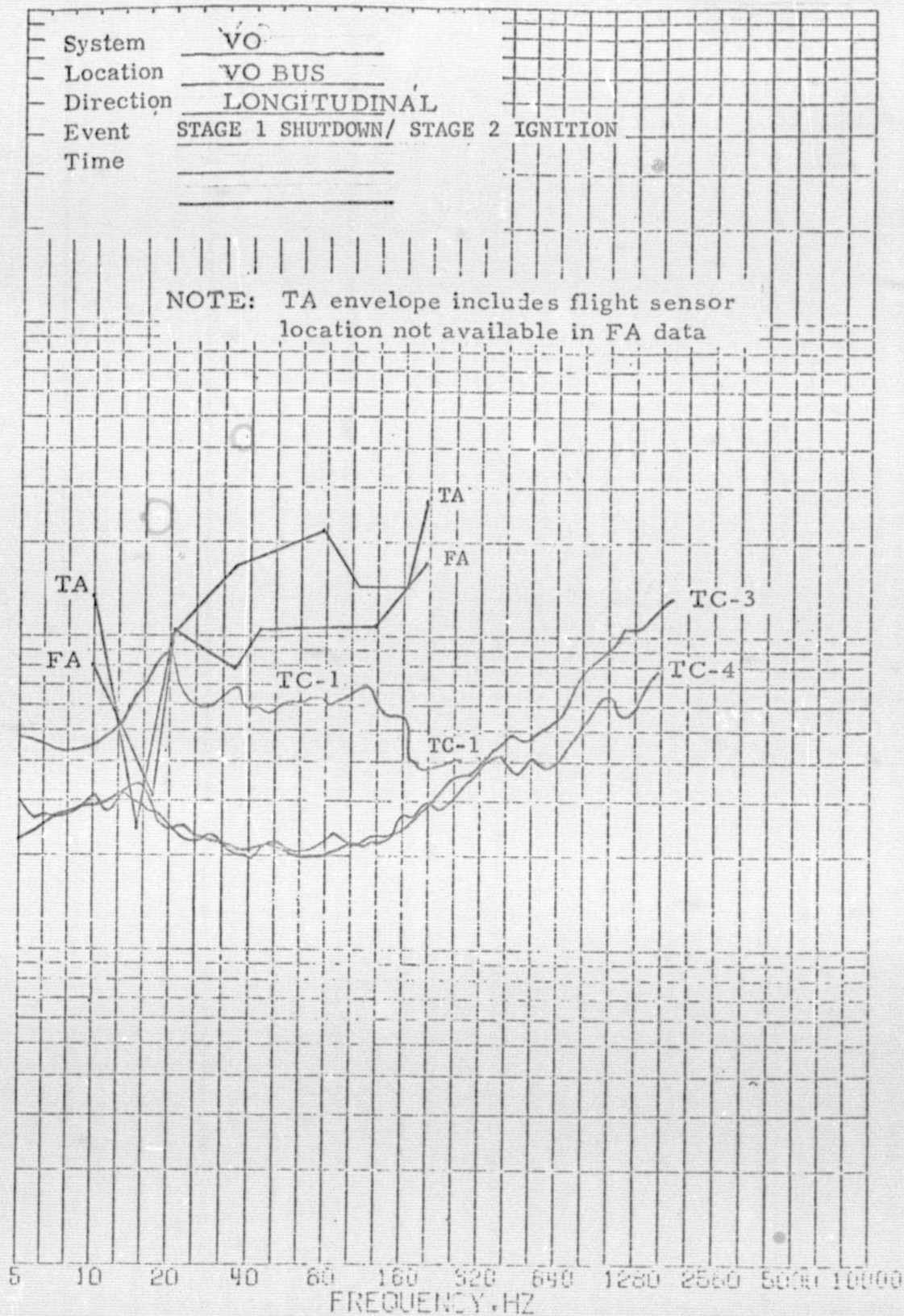
100

NOTE: TA envelope includes flight sensor  
location not available in FA data

10

1

.1



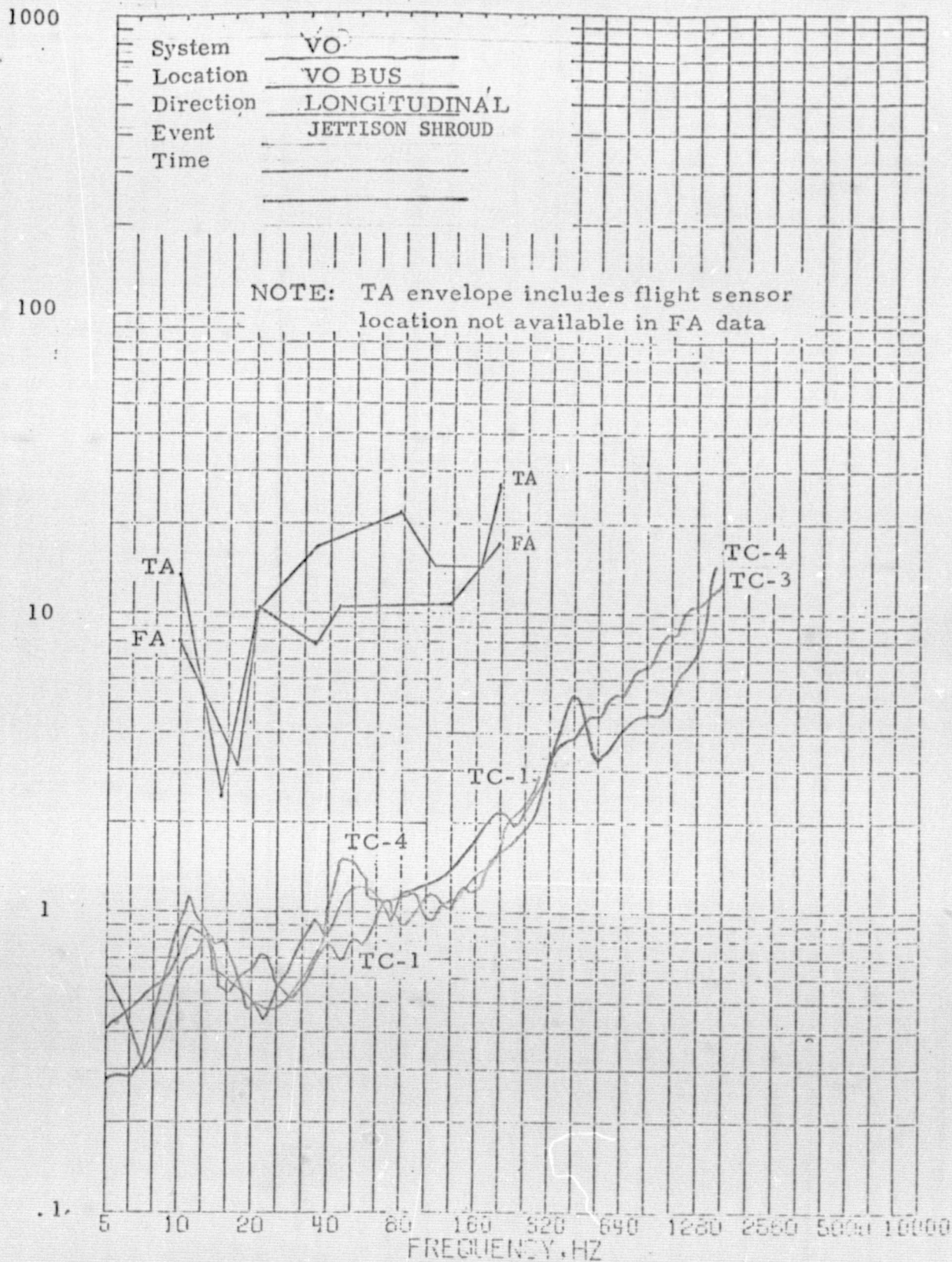


4

# SHOCK SPECTRUM

Q = 10

FIGURE 1.10



4

# SHOCK SPECTRUM

Q = 10

FIGURE 1.11

1000

System	VO
Location	VO BUS
Direction	LONGITUDINAL
Event	STAGE 2 SHUTDOWN
Time	

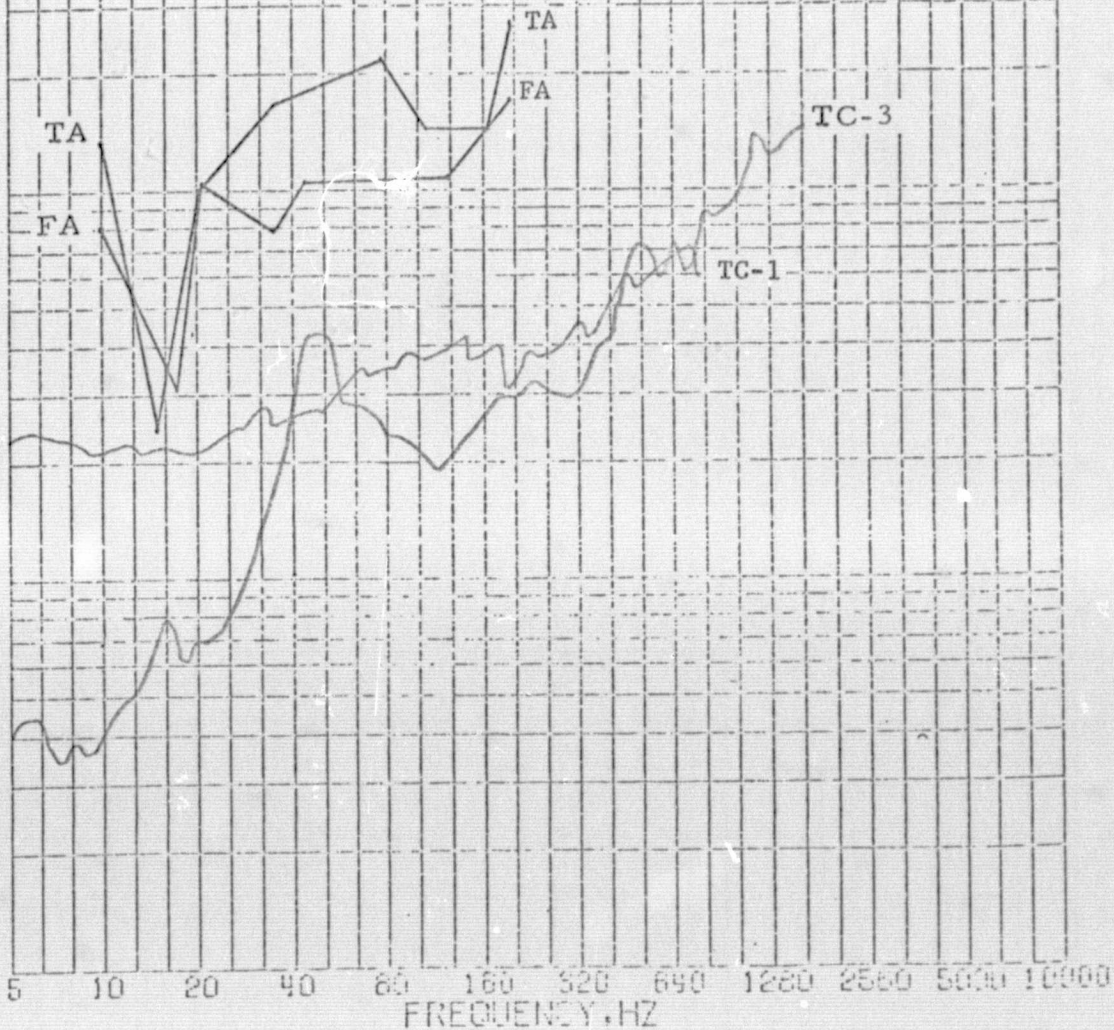
100

NOTE: TA envelope includes flight sensor  
location not available in FA data

10

1

.1



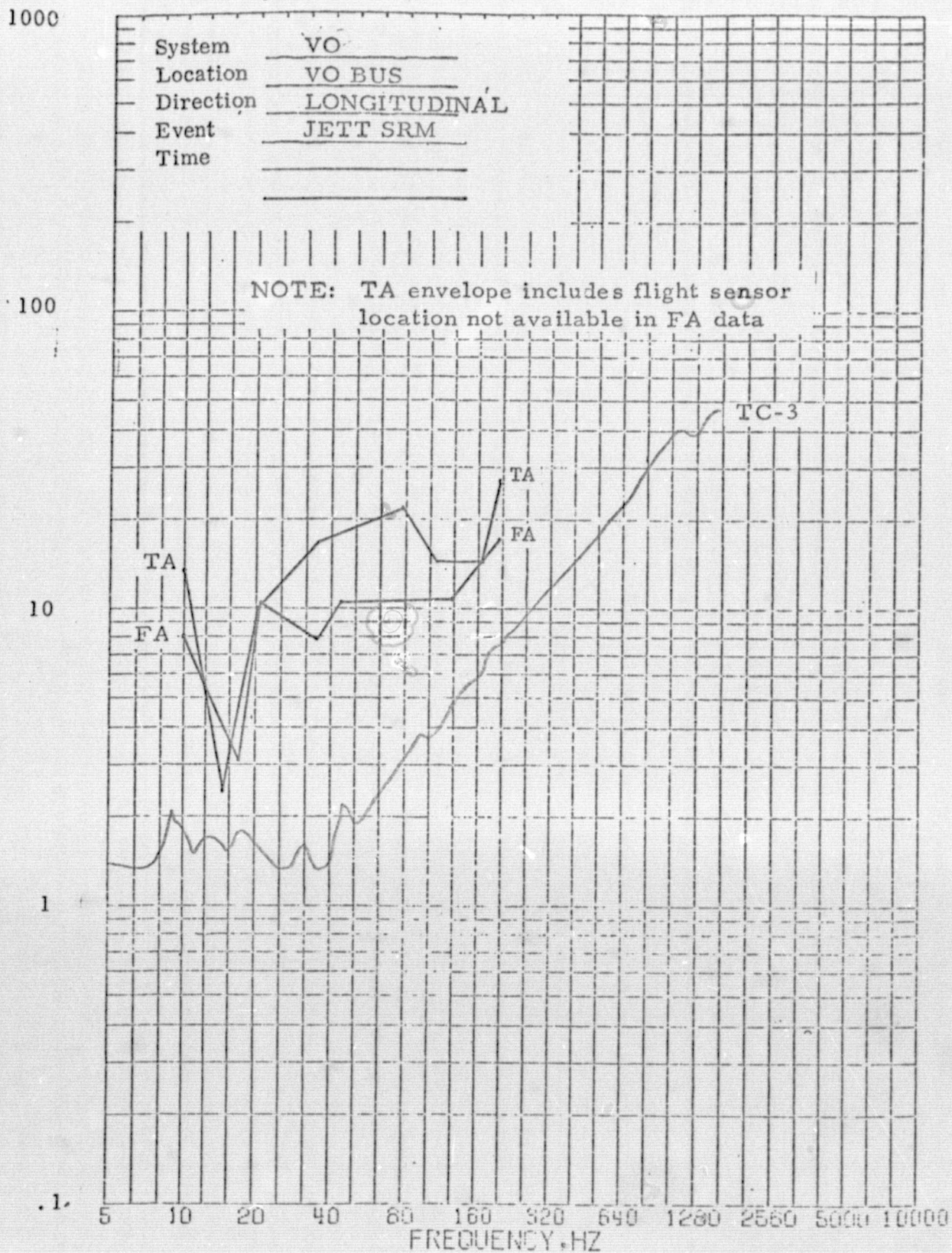


SHOCK SPECTRUM

## SHOCK SPECTRUM

$$Q = 10$$

FIGURE 1.12



System	<u>VO</u>
Location	<u>VO BUS</u>
Direction	<u>LONGITUDINAL</u>
Event	<u>JETT SRM</u>
Time	

Location	VO BUS
----------	--------

Direction LONGITUDINAL

Event	JETT SRM
-------	----------

Time

NOTE: TA envelope includes flight sensor location not available in FA data

TC-3

TA

FA

TA

FA

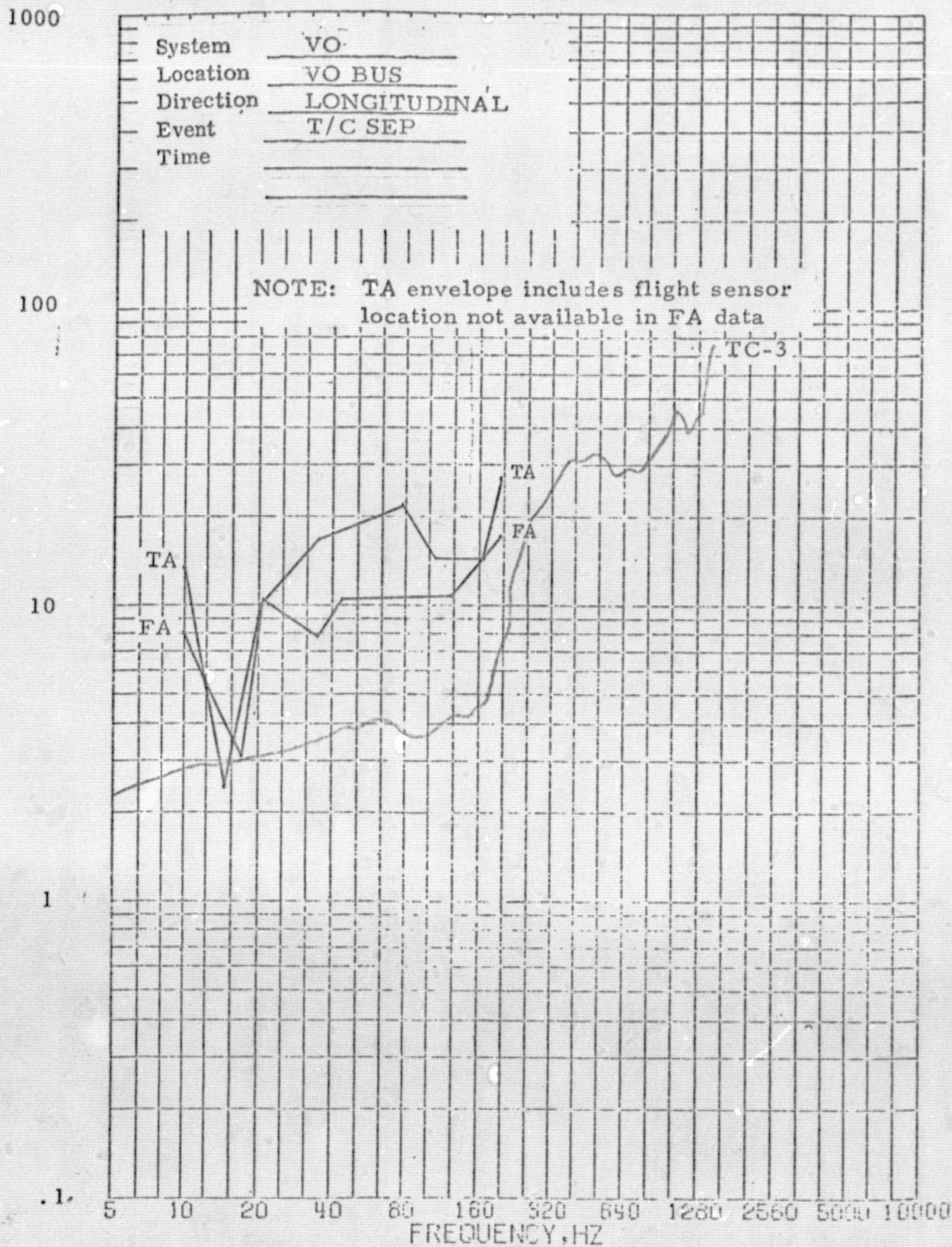
FREQUENCY, HZ

4

# SHOCK SPECTRUM

Q = 10

FIGURE 1.13



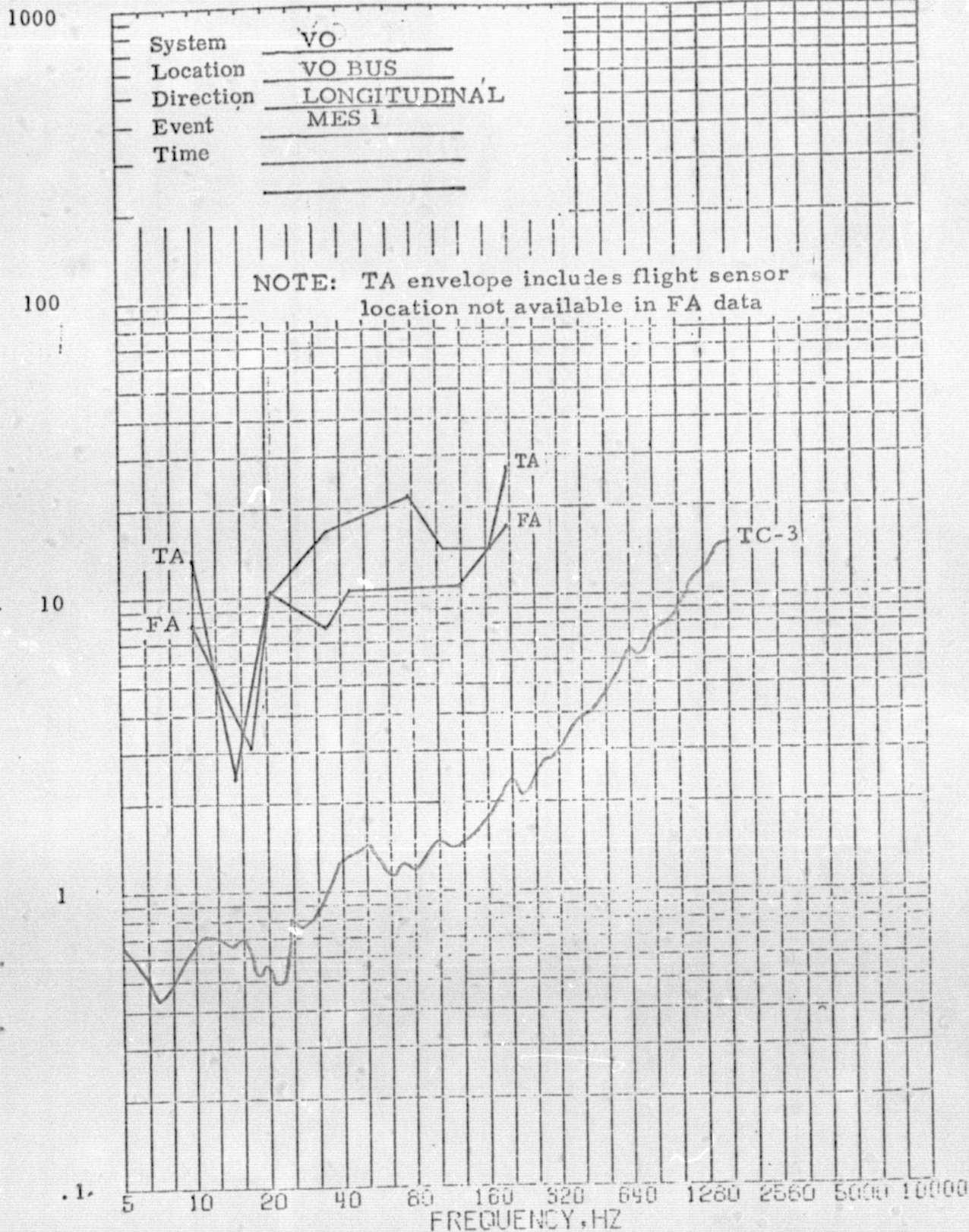


4

# SHOCK SPECTRUM

Q = 10

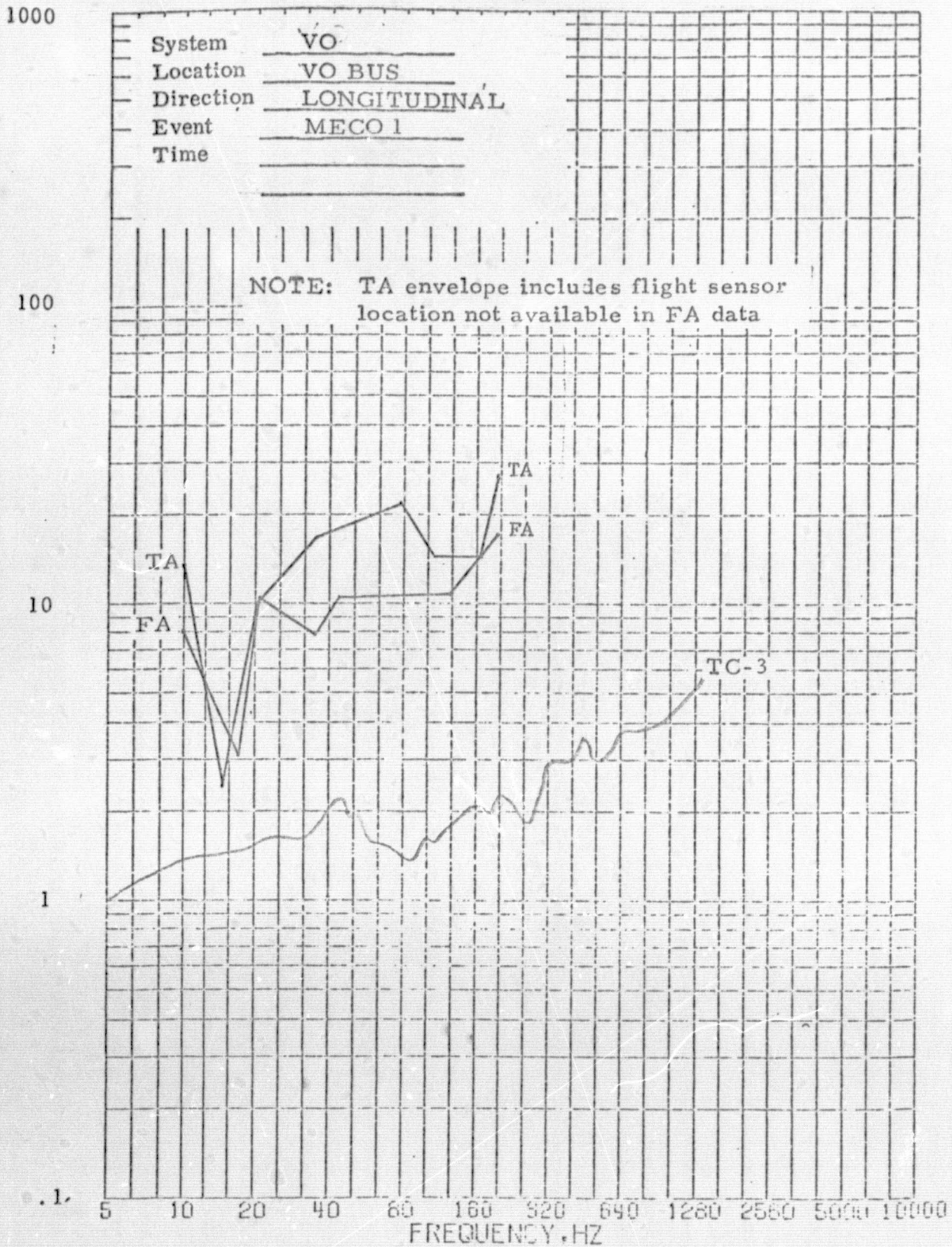
FIGURE 1.14



4

# SHOCK SPECTRUM Q = 10

FIGURE 1.15





4

# SHOCK SPECTRUM

Q = 10

FIGURE 1.16

1000

System	VO
Location	VO BUS
Direction	LONGITUDINAL
Event	MES 2
Time	

100

NOTE: TA envelope includes flight sensor  
location not available in FA data

10

TA

FA

TA

FA

1

TC-3

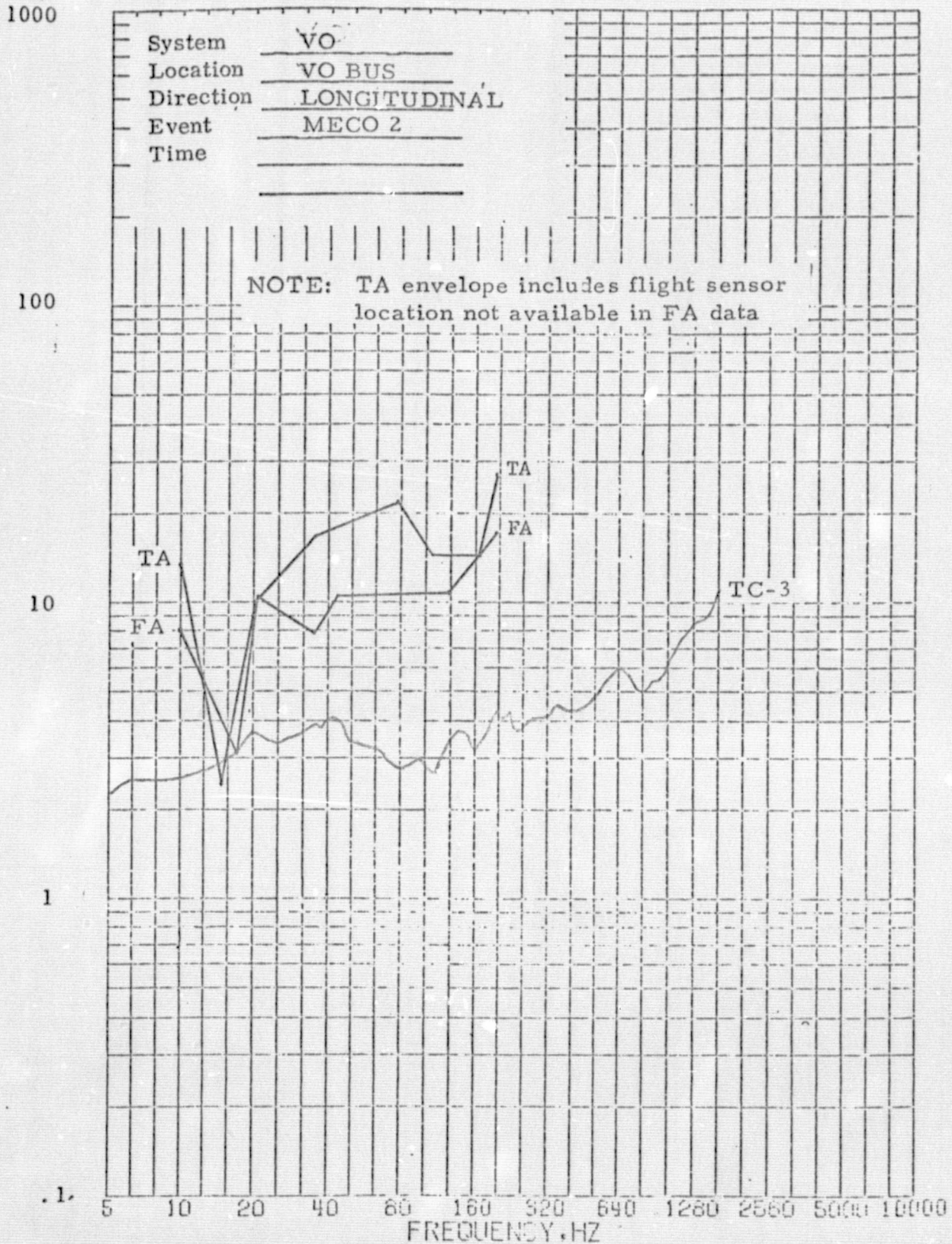
.1

5 10 20 40 80 160 320 640 1280 2560 5000 10000  
FREQUENCY, HZ

4

# SHOCK SPECTRUM Q = 10

FIGURE 1.17





(5)

# SHOCK SPECTRUM Q = 10

FIGURE 1.18

1000

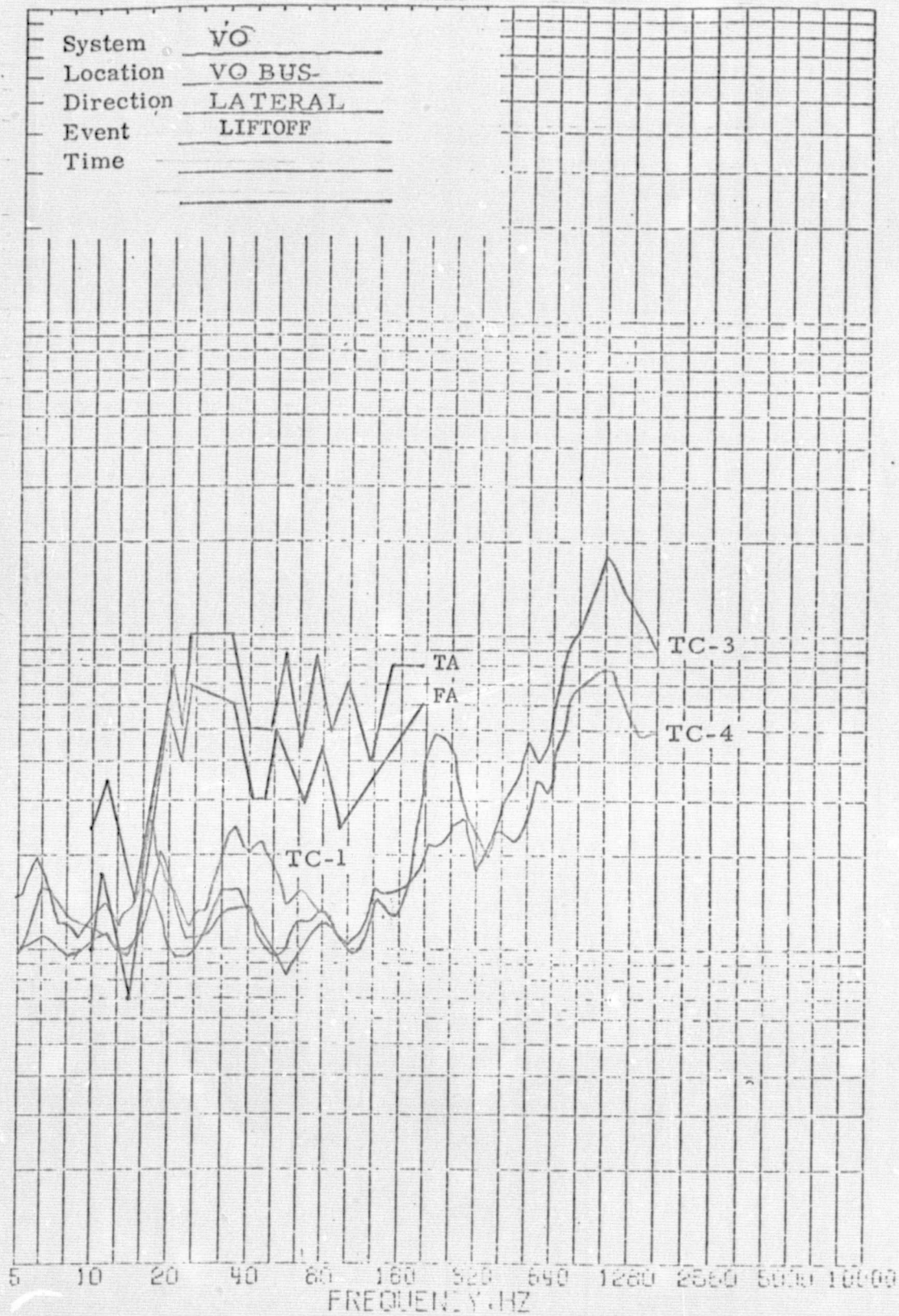
System	VO
Location	VO BUS
Direction	LATERAL
Event	LIFTOFF
Time	

100

10

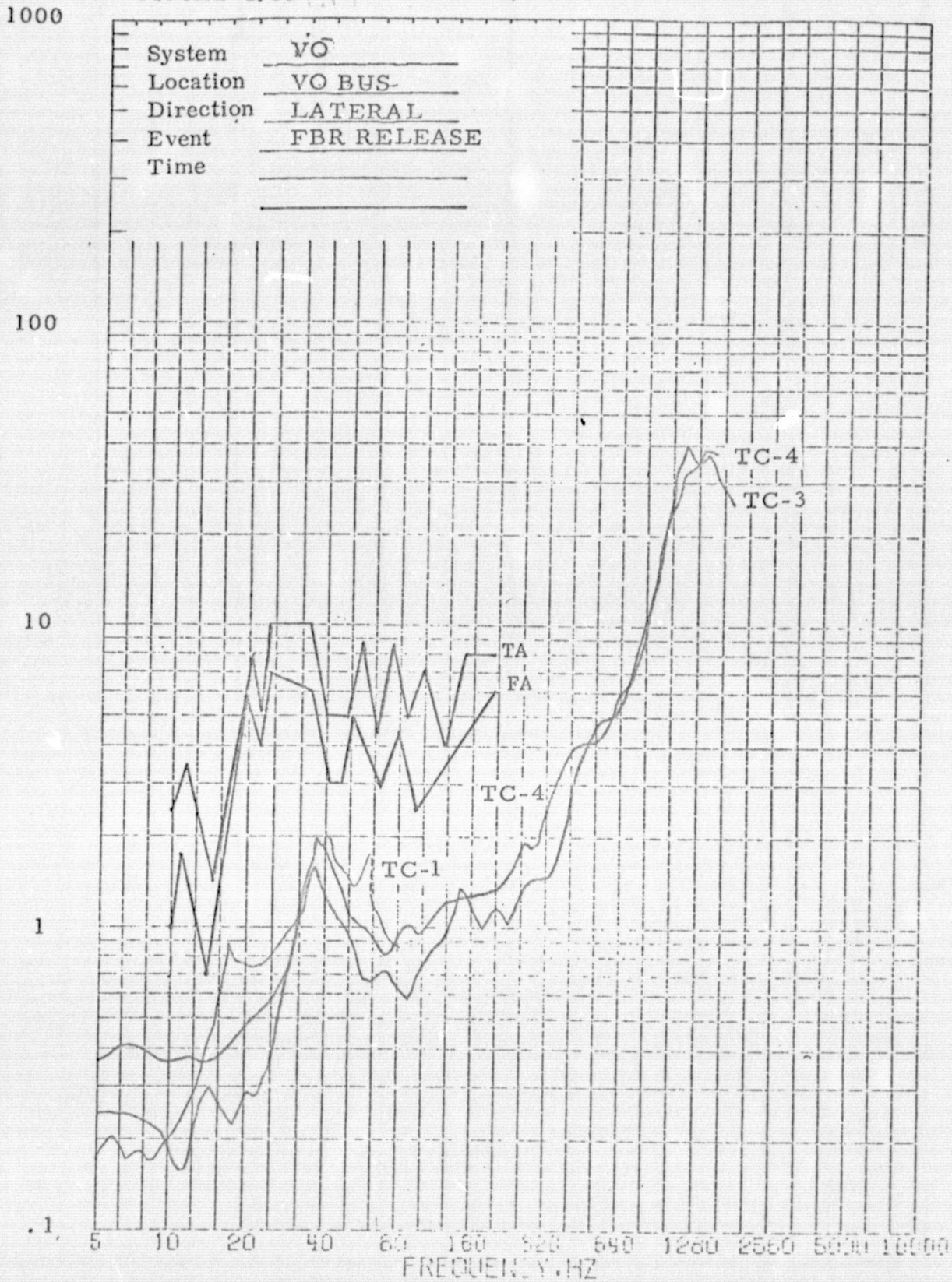
1

.1



SHOCK SPECTRUM  
Q = 10

FIGURE 1.19





5

# SHOCK SPECTRUM Q = 10

FIGURE 1.201.20

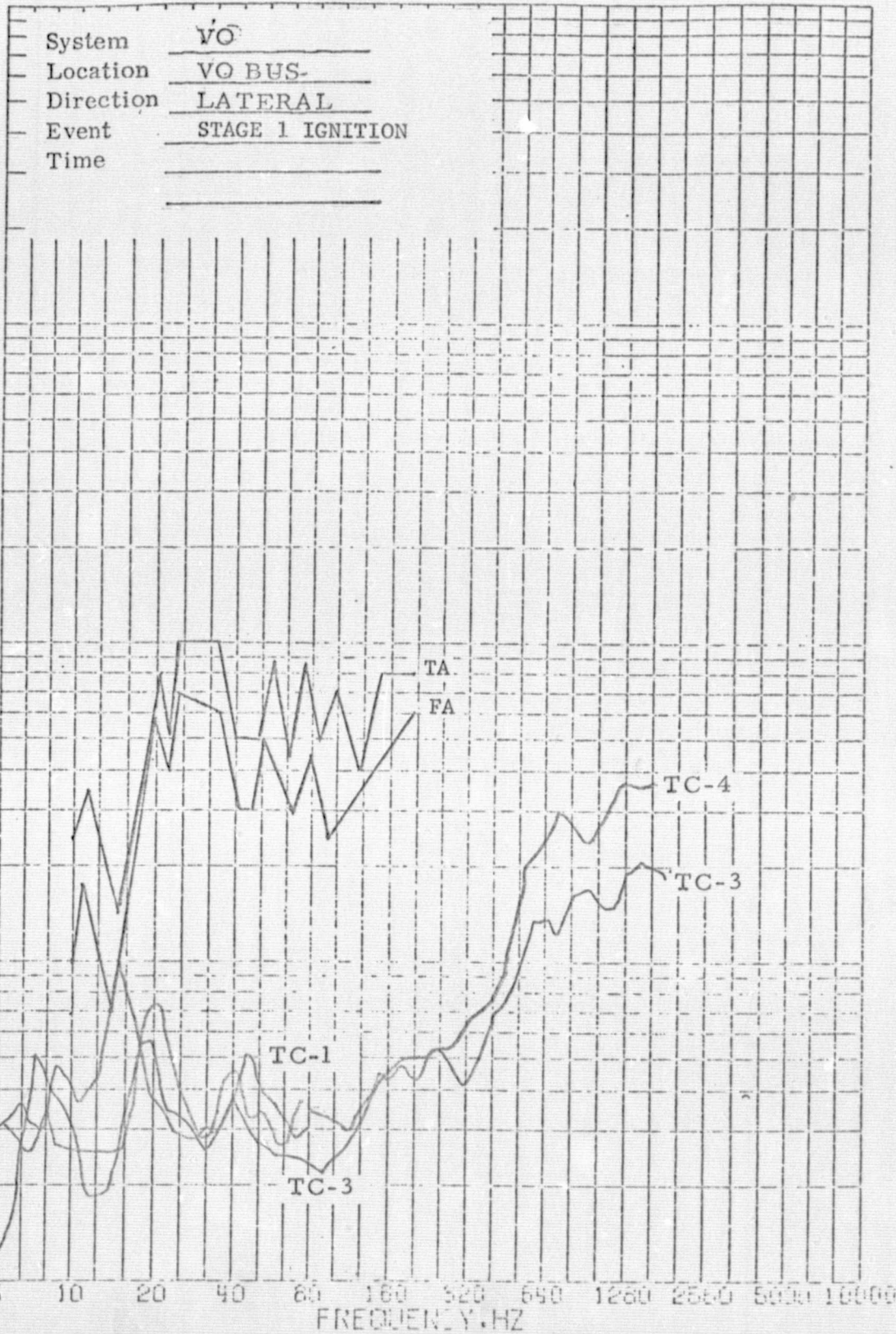
1000

100

10

1

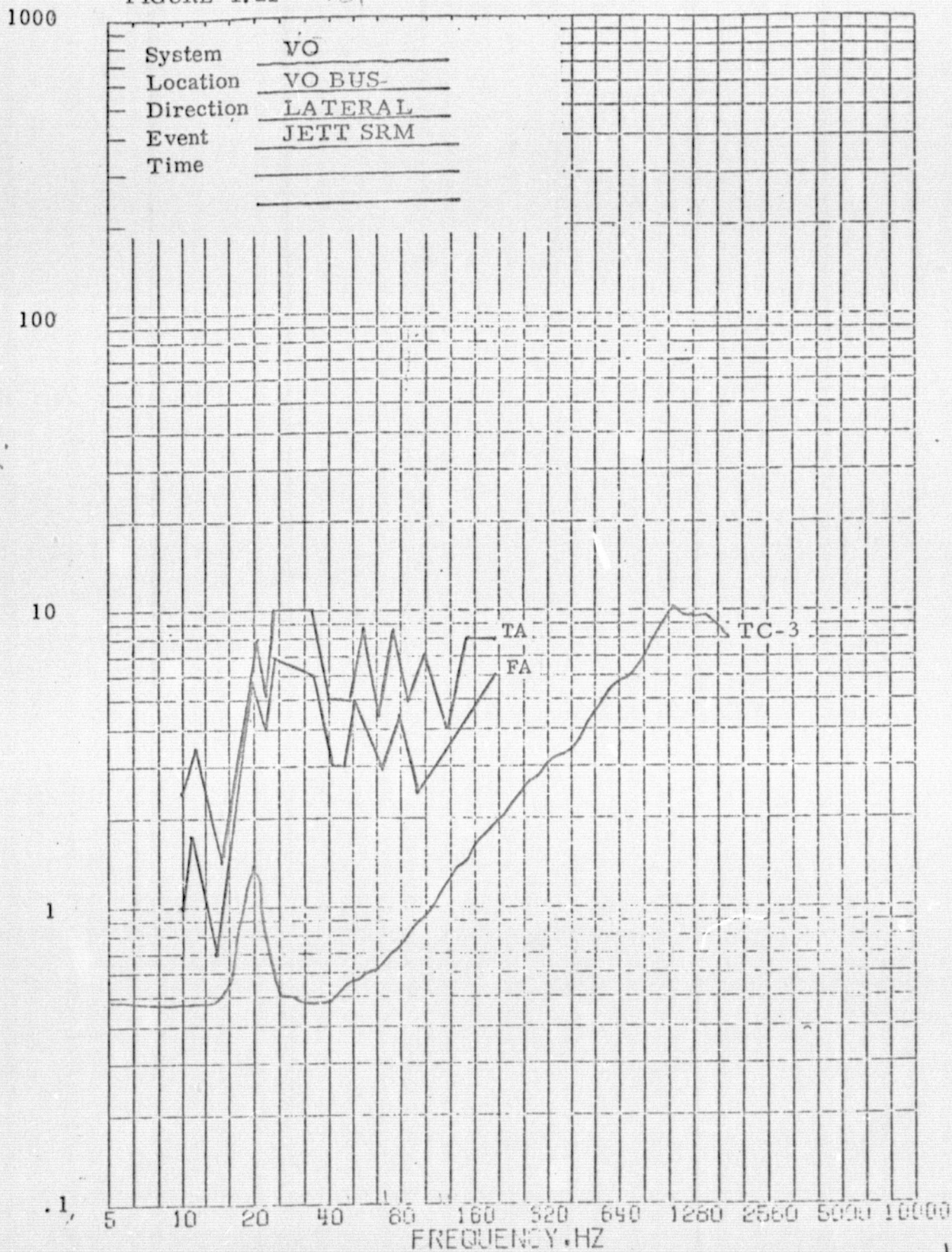
.1



5

# SHOCK SPECTRUM Q = 10

FIGURE 1.21 1.21

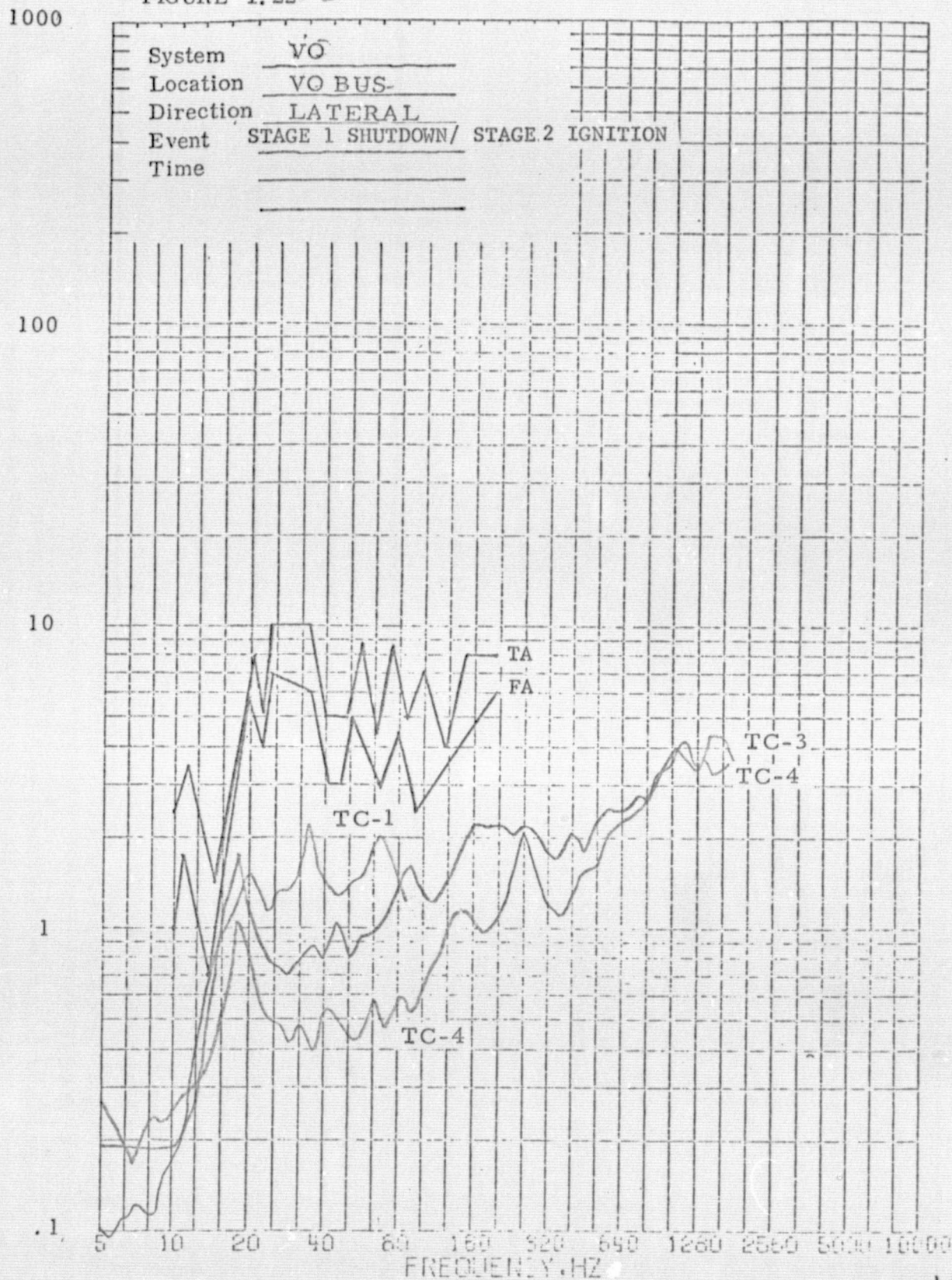




5

# SHOCK SPECTRUM Q = 10

FIGURE 1.22



5

# SHOCK SPECTRUM

FIGURE 1.23 1.23

Q=10

1000

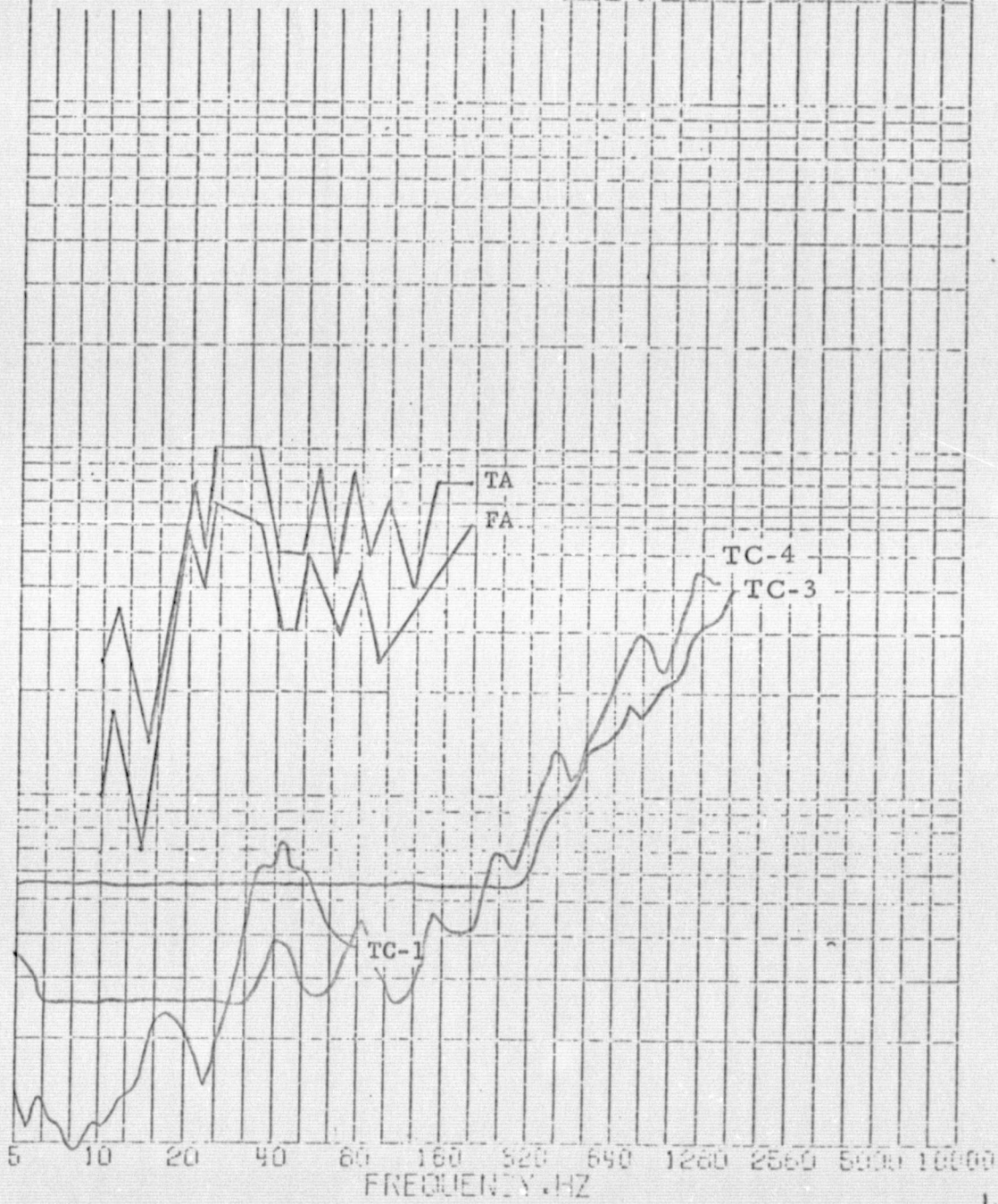
System	VO
Location	VO BUS
Direction	LATERAL
Event	JETTISON SHROUD
Time	

100

10

1

.1





5

# SHOCK SPECTRUM

FIGURE 1.24 1.24

Q = 10

1000

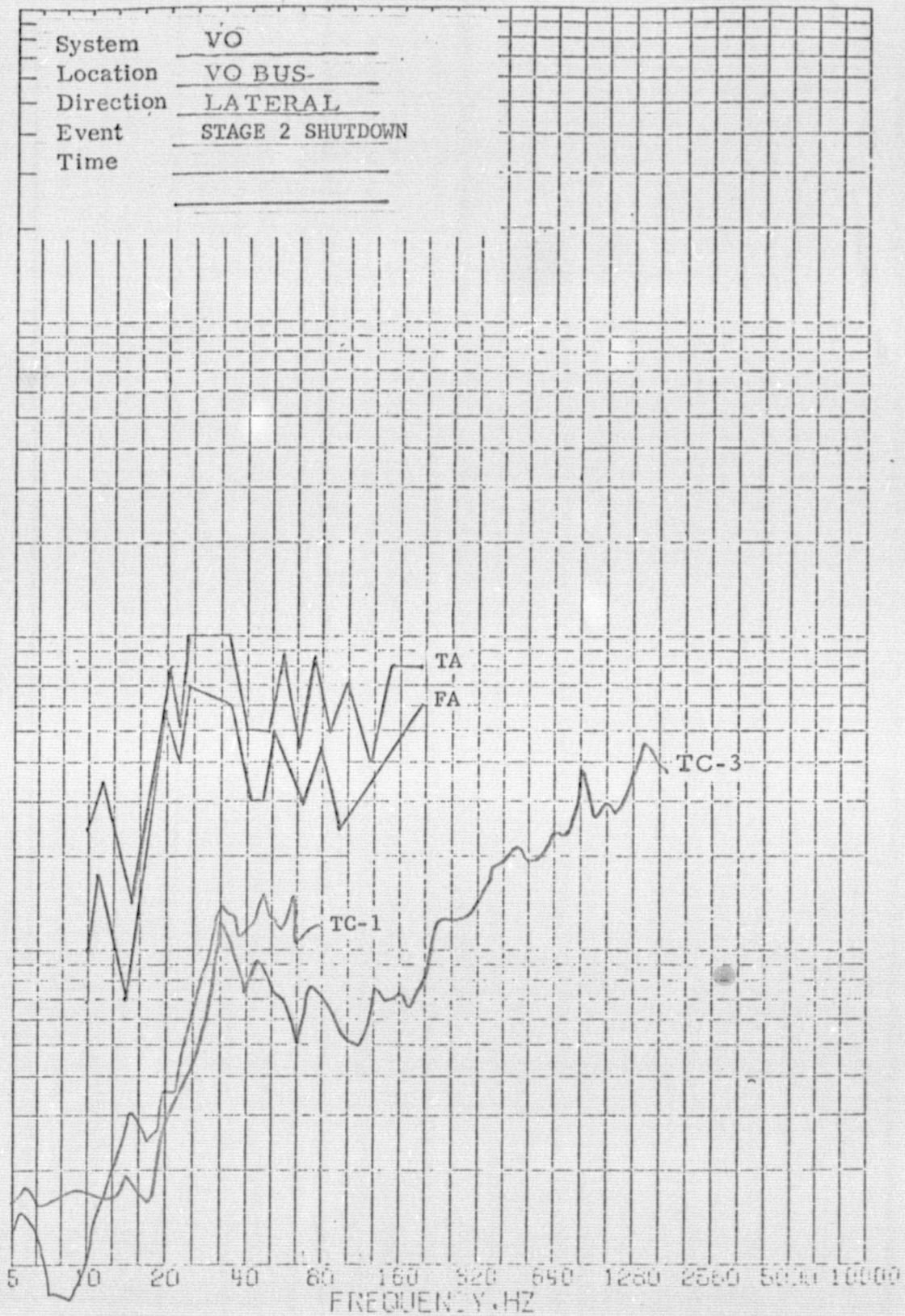
System	VO
Location	VO BUS-
Direction	LATERAL
Event	STAGE 2 SHUTDOWN
Time	

100

10

1

.1



1.25

5

# SHOCK SPECTRUM Q = 10

FIGURE 1.25

1000

System	VO
Location	VO BUS
Direction	LATERAL
Event	T/C SEP
Time	

100

10

TC-3

TA

FA

1

.1

5 10 20 40 80 160 320 640 1280 2560 5000 10000  
FREQUENCY, HZ



5

# SHOCK SPECTRUM Q=10

FIGURE 1.26

1000

System	VO
Location	VO BUS
Direction	LATERAL
Event	MES 1
Time	

100

10

1

.1

5 10 20 40 80 160 320 640 1280 2560 5000 10000  
FREQUENCY .HZ

1.27

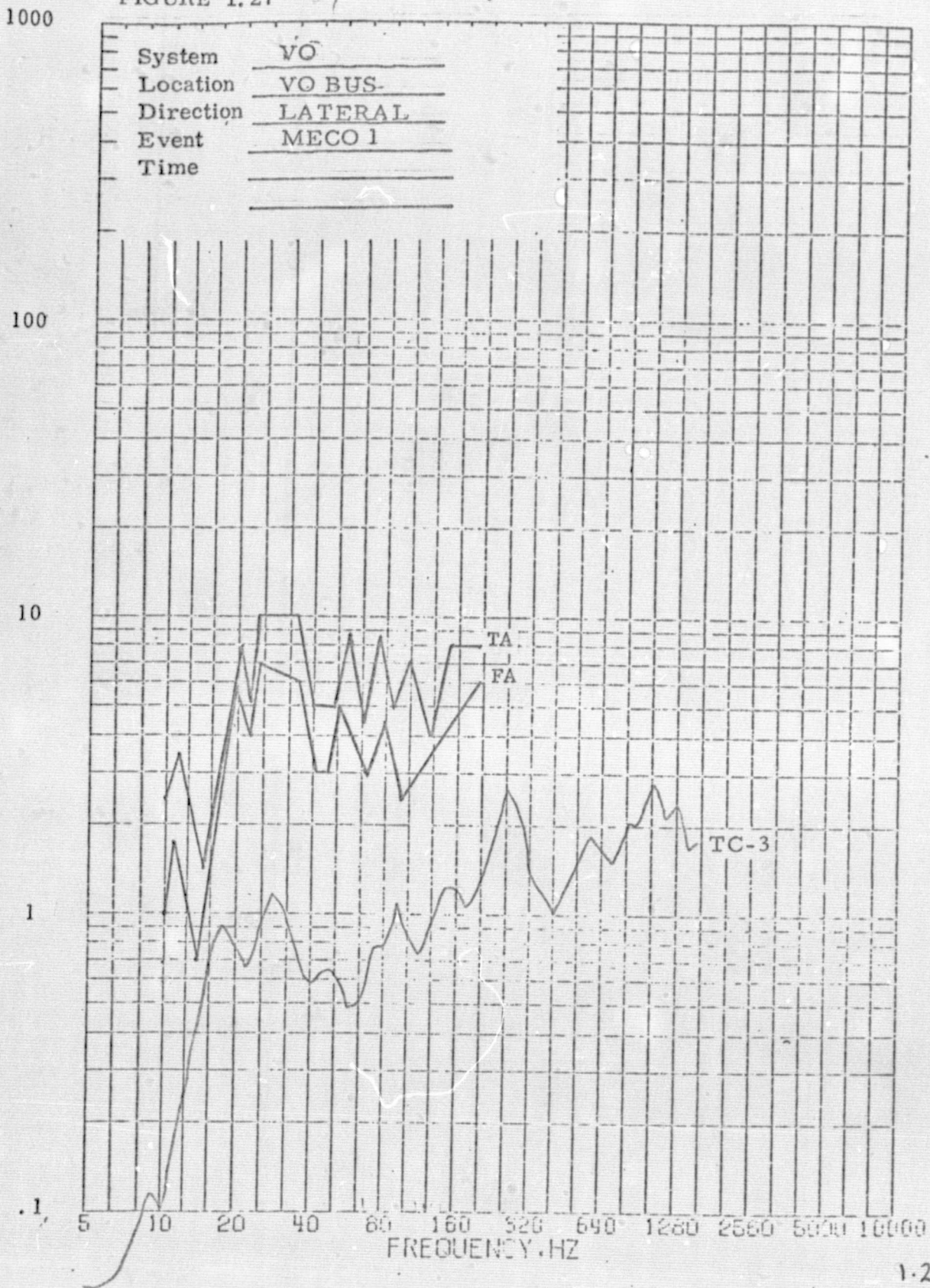
TA  
FA

TC-3

(5)

# SHOCK SPECTRUM Q = 10

FIGURE 1.27





(5)

# SHOCK SPECTRUM

Q = 10

FIGURE 1.28 1.28

1000

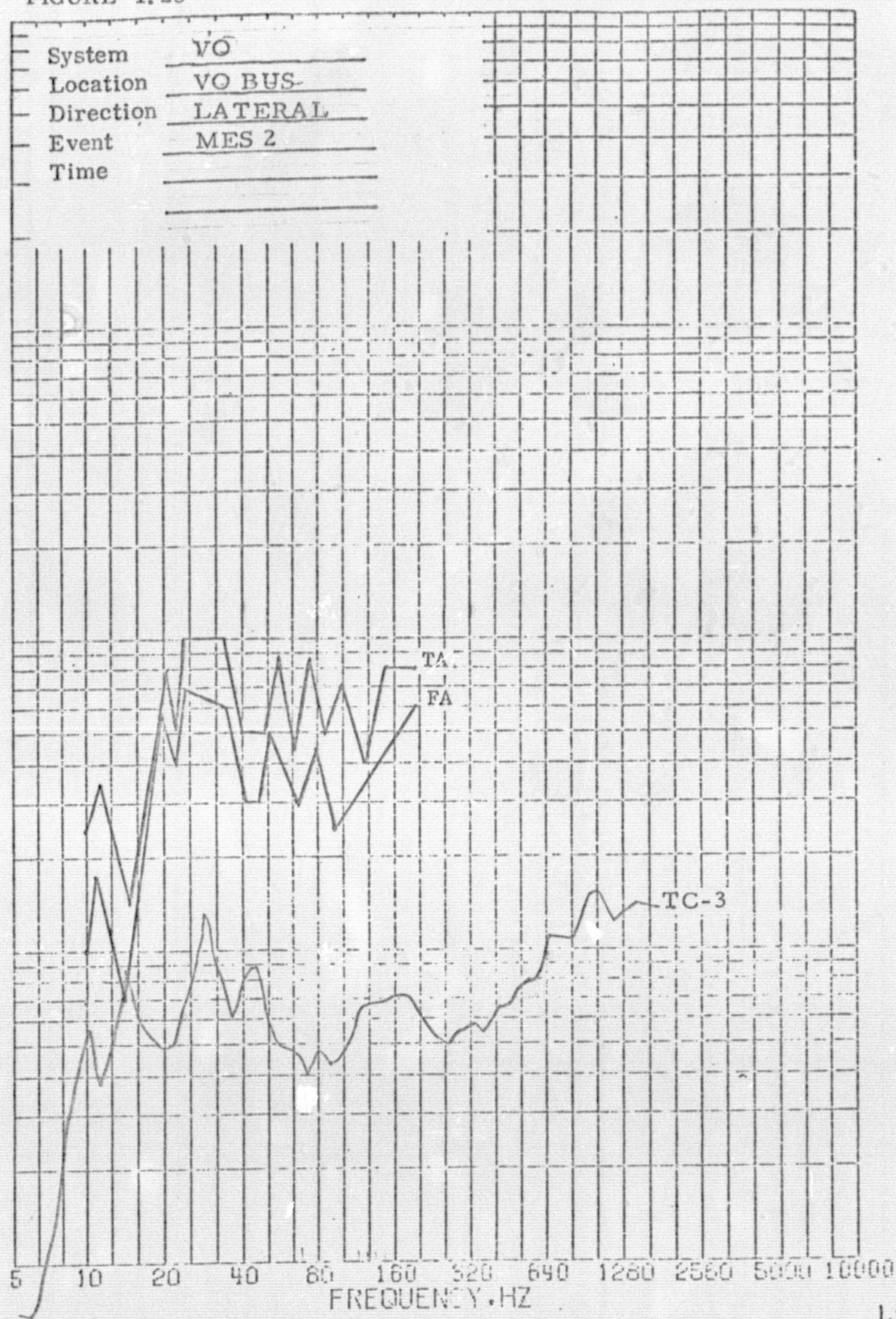
System	VO
Location	VO BUS
Direction	LATERAL
Event	MES 2
Time	

100

10

1

.1



5

# SHOCK SPECTRUM

Q = 10

FIGURE 1.29 1.29

1000

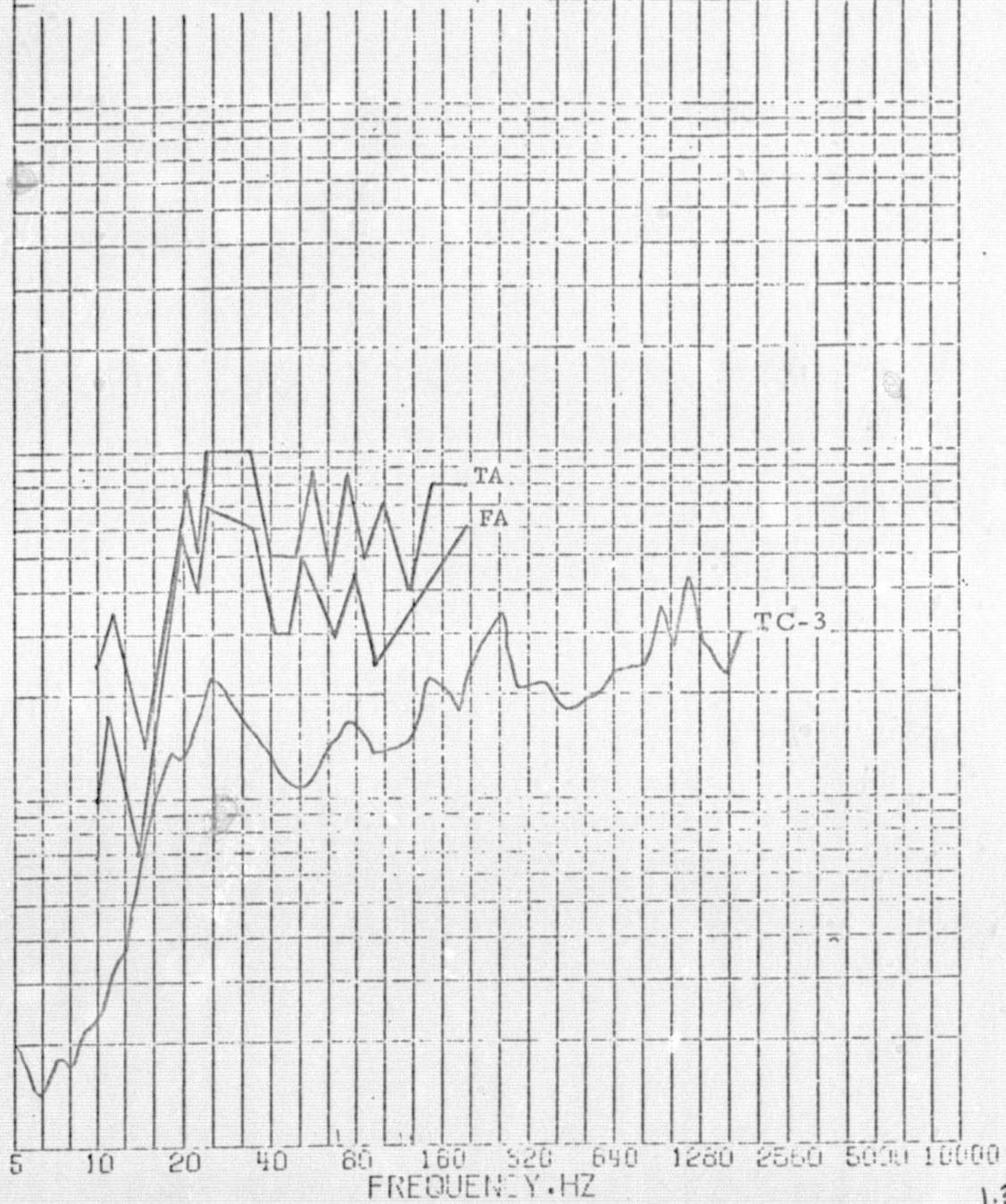
System	VO
Location	VO BUS
Direction	LATERAL
Event	MECO 2
Time	

100

10

1

.1



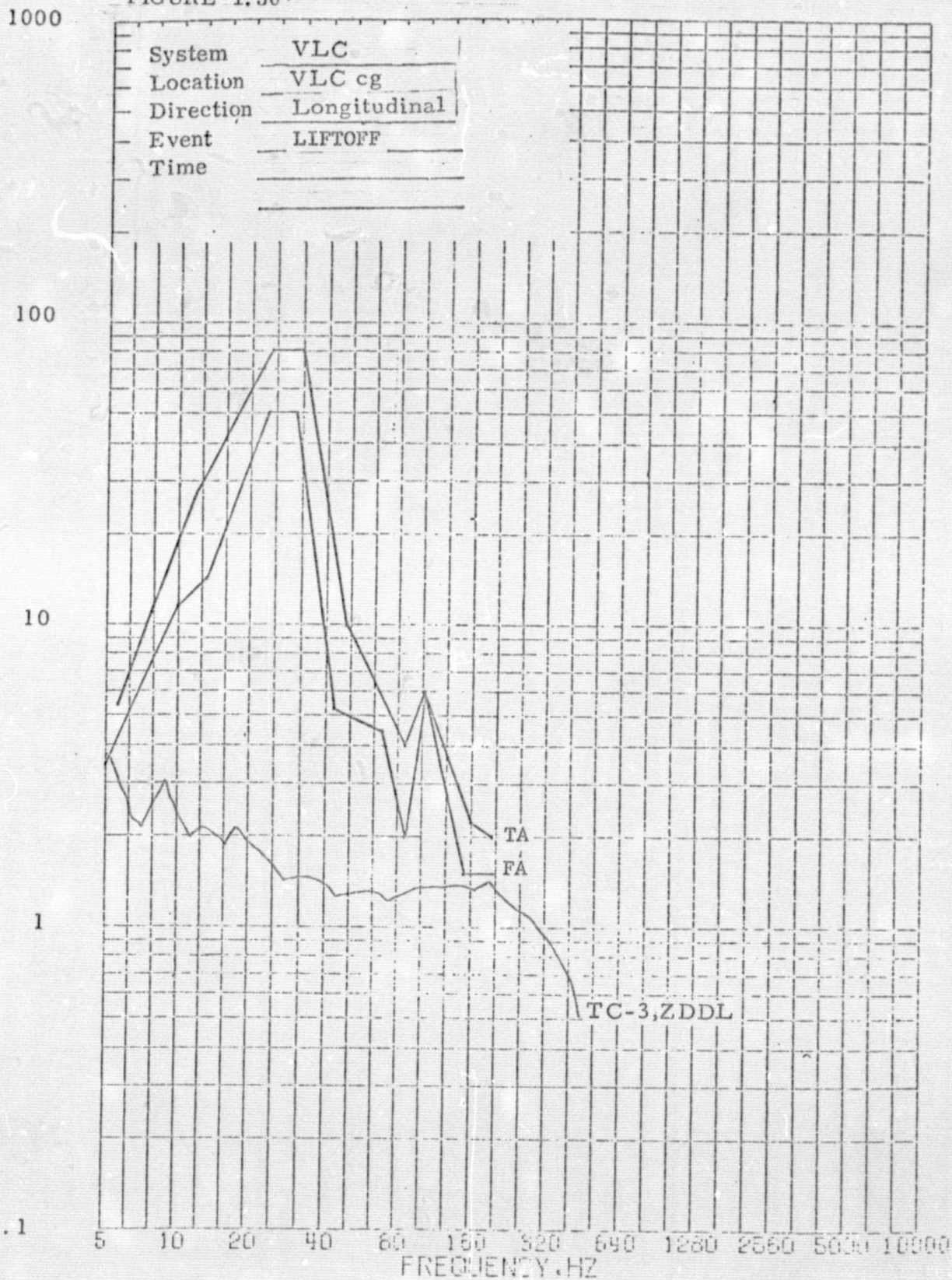
1.30



3

# SHOCK SPECTRUM Q = 10

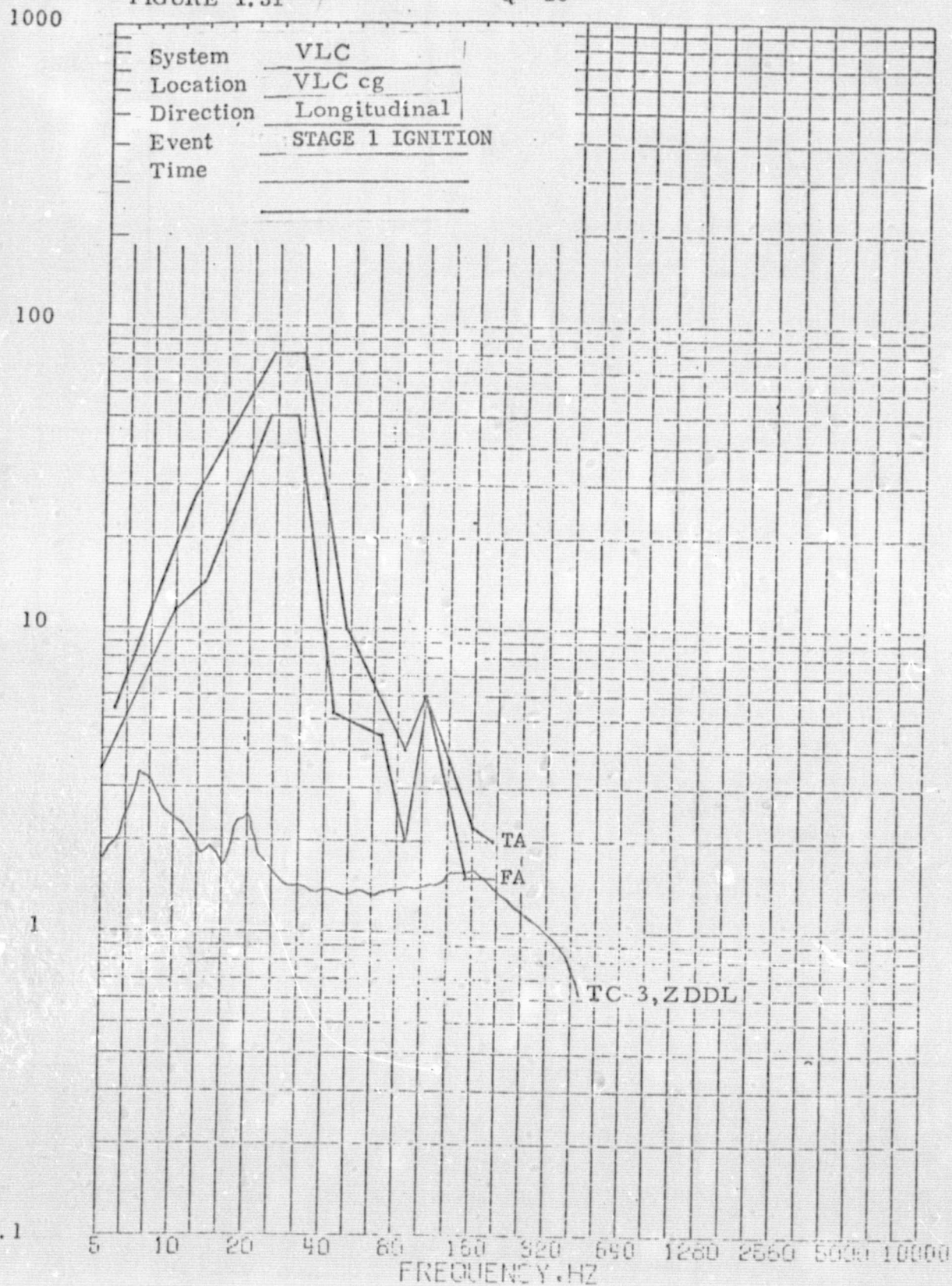
FIGURE 1.30



2

# SHOCK SPECTRUM Q = 10

FIGURE 1.31

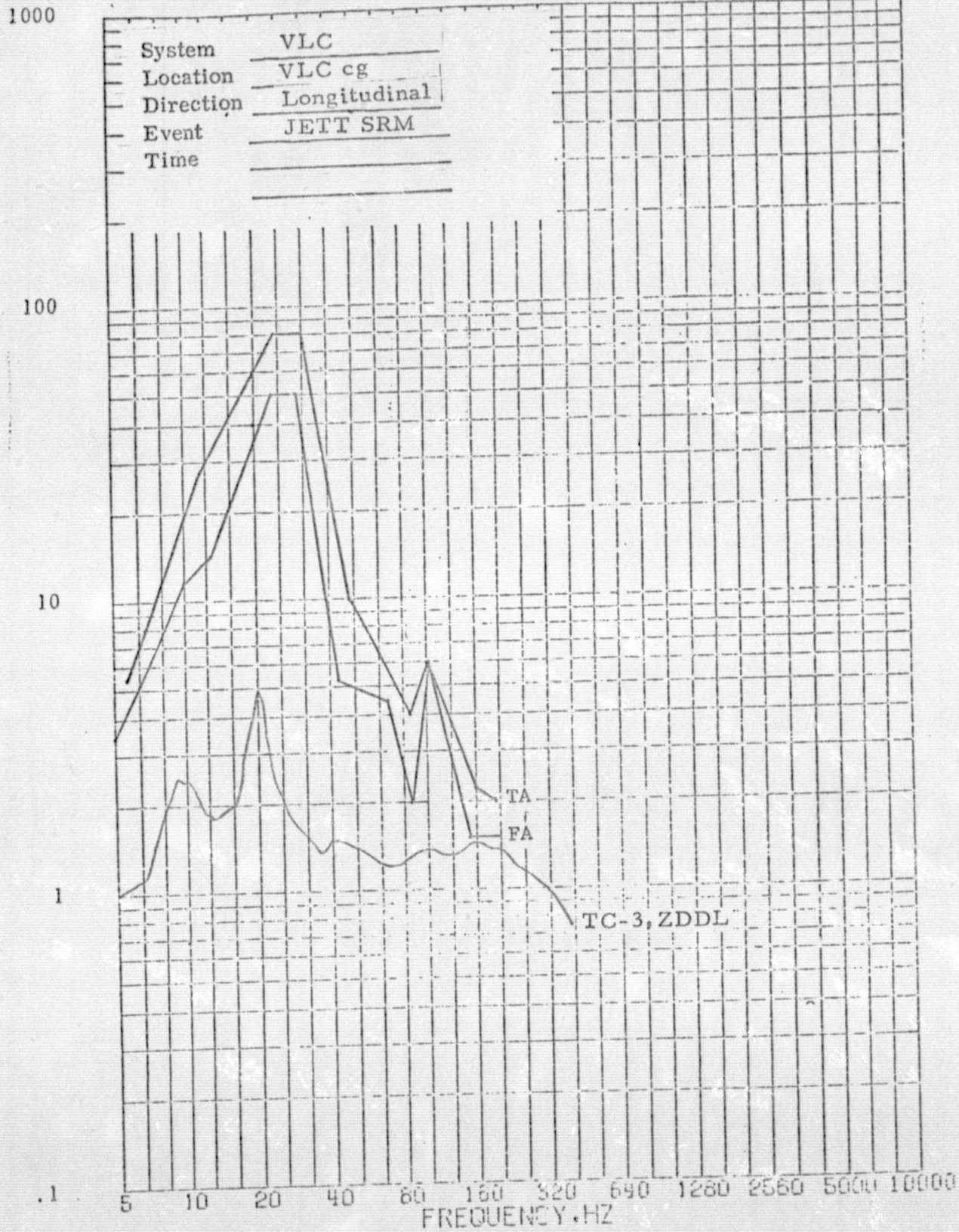




2

# SHOCK SPECTRUM Q = 10

FIGURE 1.32

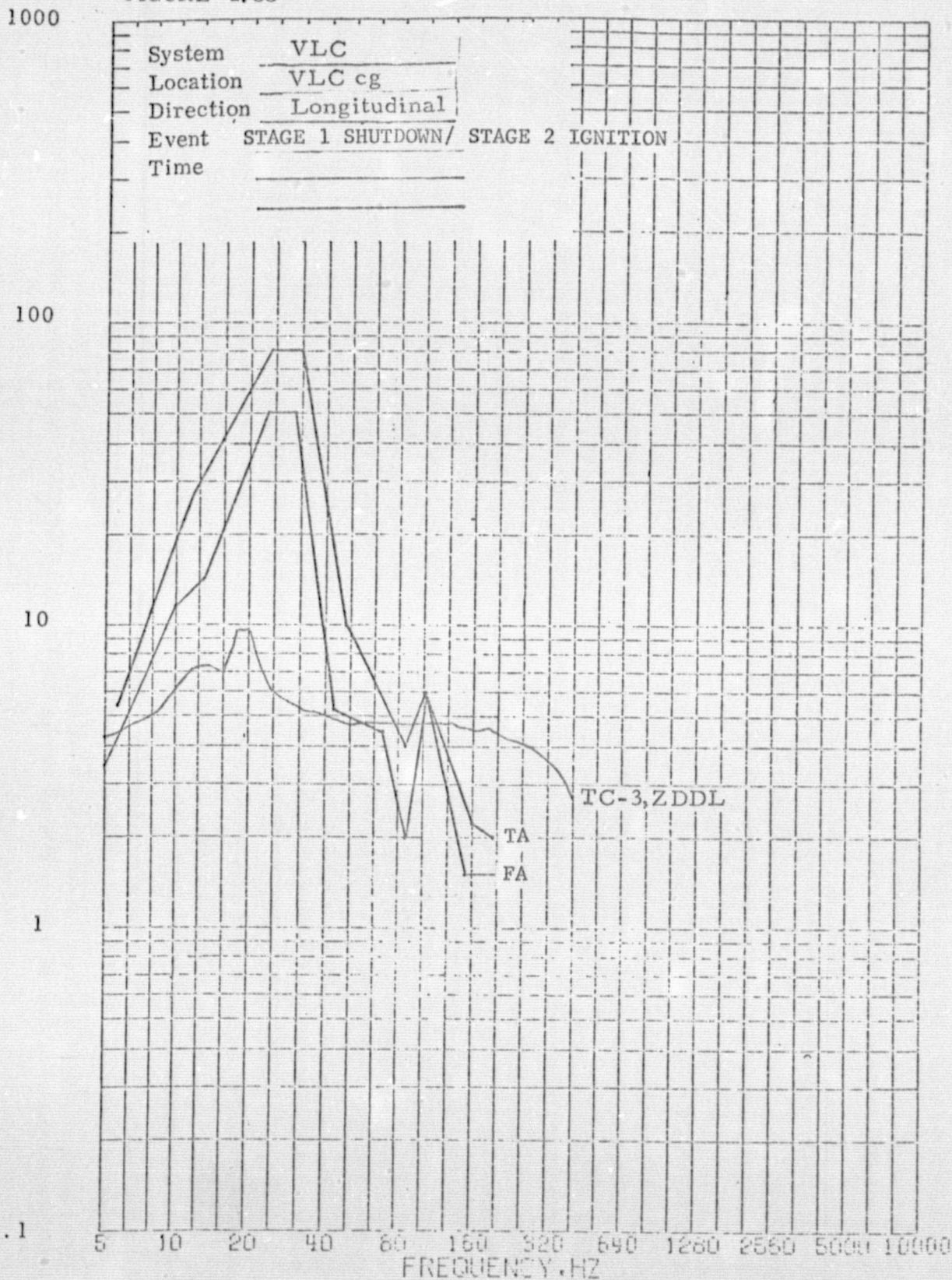




3

# SHOCK SPECTRUM Q = 10

FIGURE 1.33



3

# SHOCK SPECTRUM Q = 10

FIGURE 1.34

1000

System	VLC
Location	VLC cg
Direction	Longitudinal
Event	JETTISON SHROUD
Time	

100

10

1

.1

5 10 20 40 60 160 320 640 1280 2560 5000 10000  
FREQUENCY, HZ

TA  
FA

TC-3, ZDDL

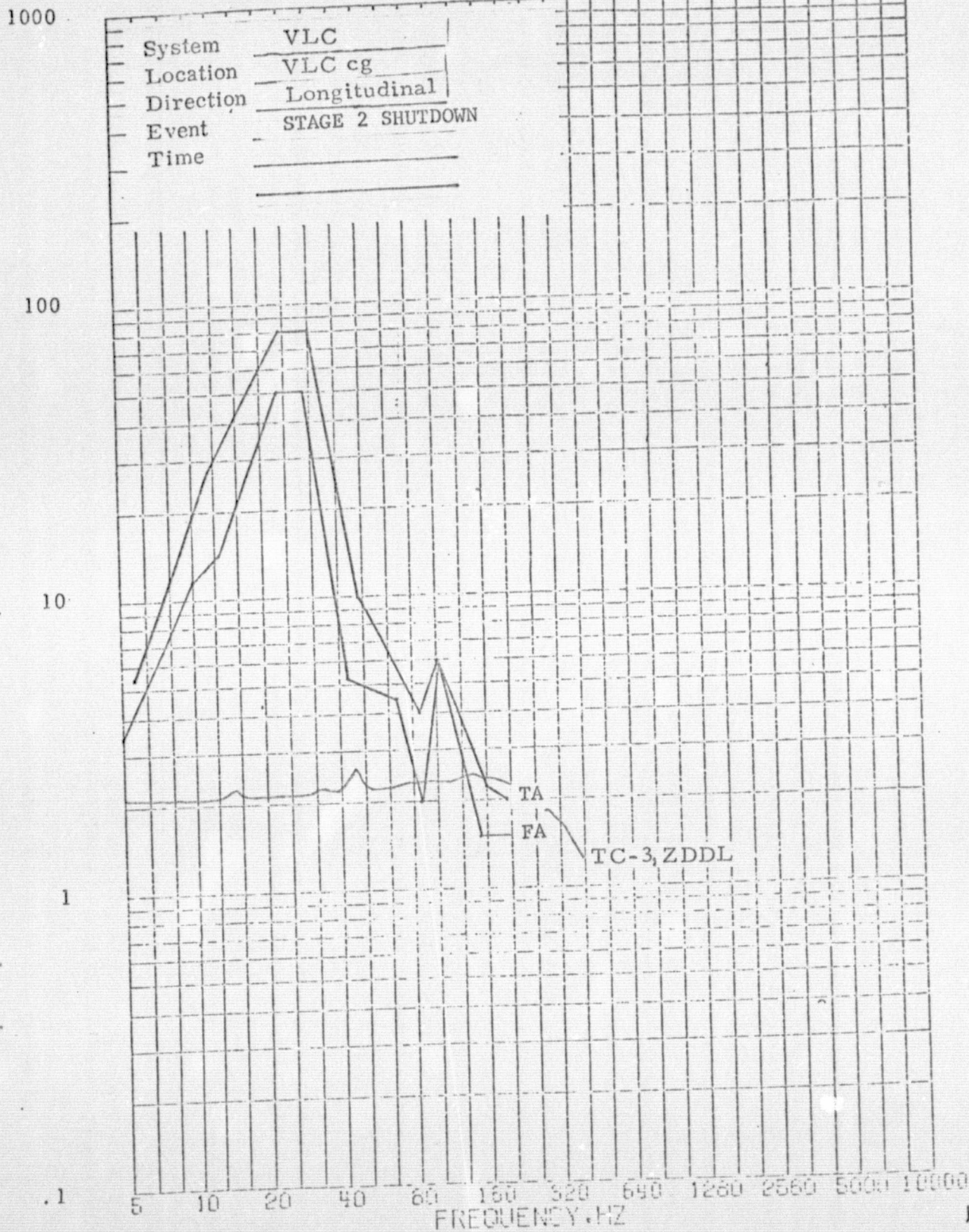
1.35



2

# SHOCK SPECTRUM Q = 10

FIGURE 1.35





2

# SHOCK SPECTRUM Q = 10

FIGURE 1.36 1.36

1000

System	VLC
Location	VLC cg
Direction	Longitudinal
Event	MES 1
Time	

100

10

1

.1

5 10 20 40 60 160 320 640 1280 2560 5000 10000  
FREQUENCY - HZ

TA  
FA

TC-3, ZDDL

3

# SHOCK SPECTRUM Q = 10

FIGURE 1.37

1000

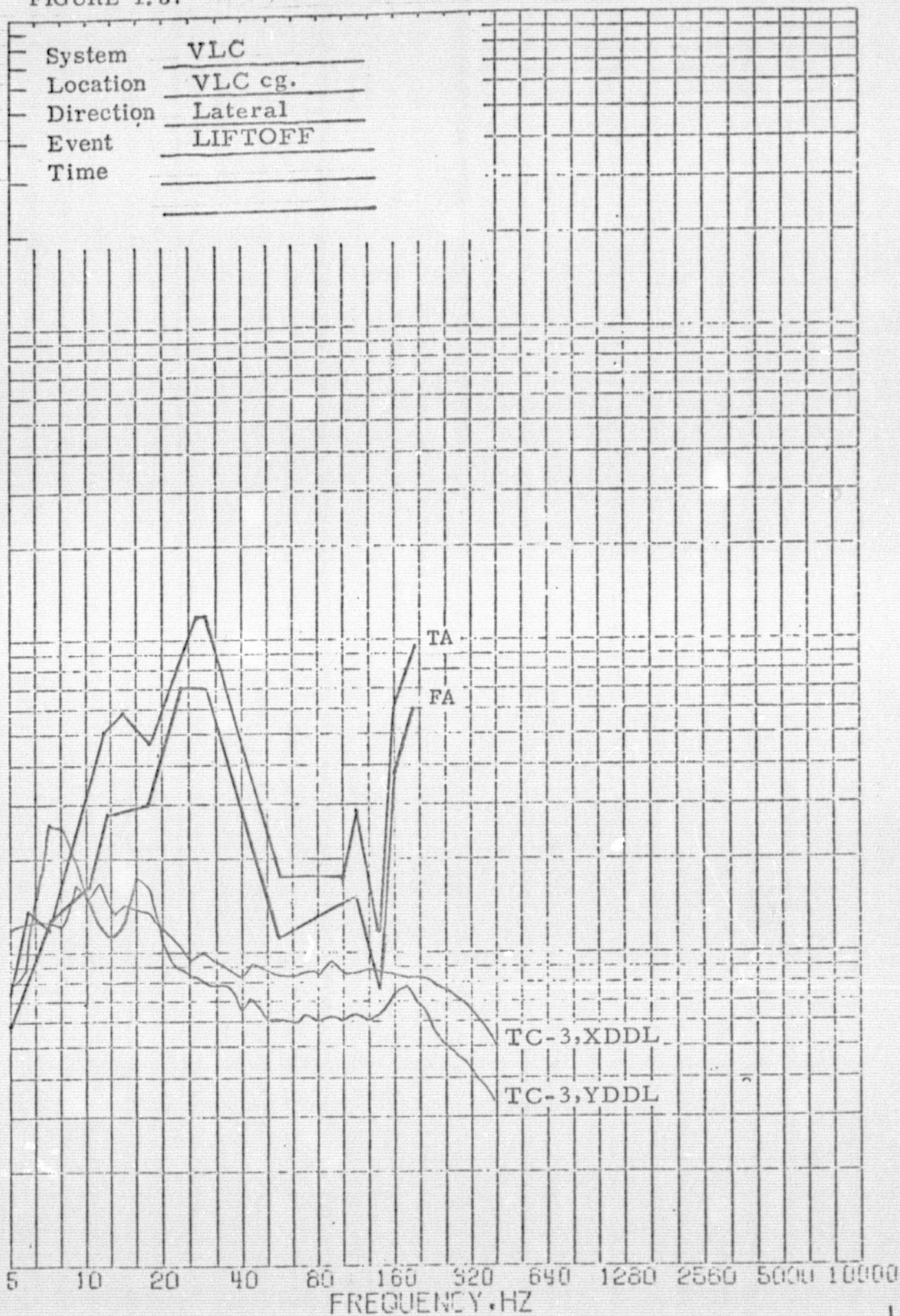
System	VLC
Location	VLC cg.
Direction	Lateral
Event	LIFTOFF
Time	

100

10

1

.1





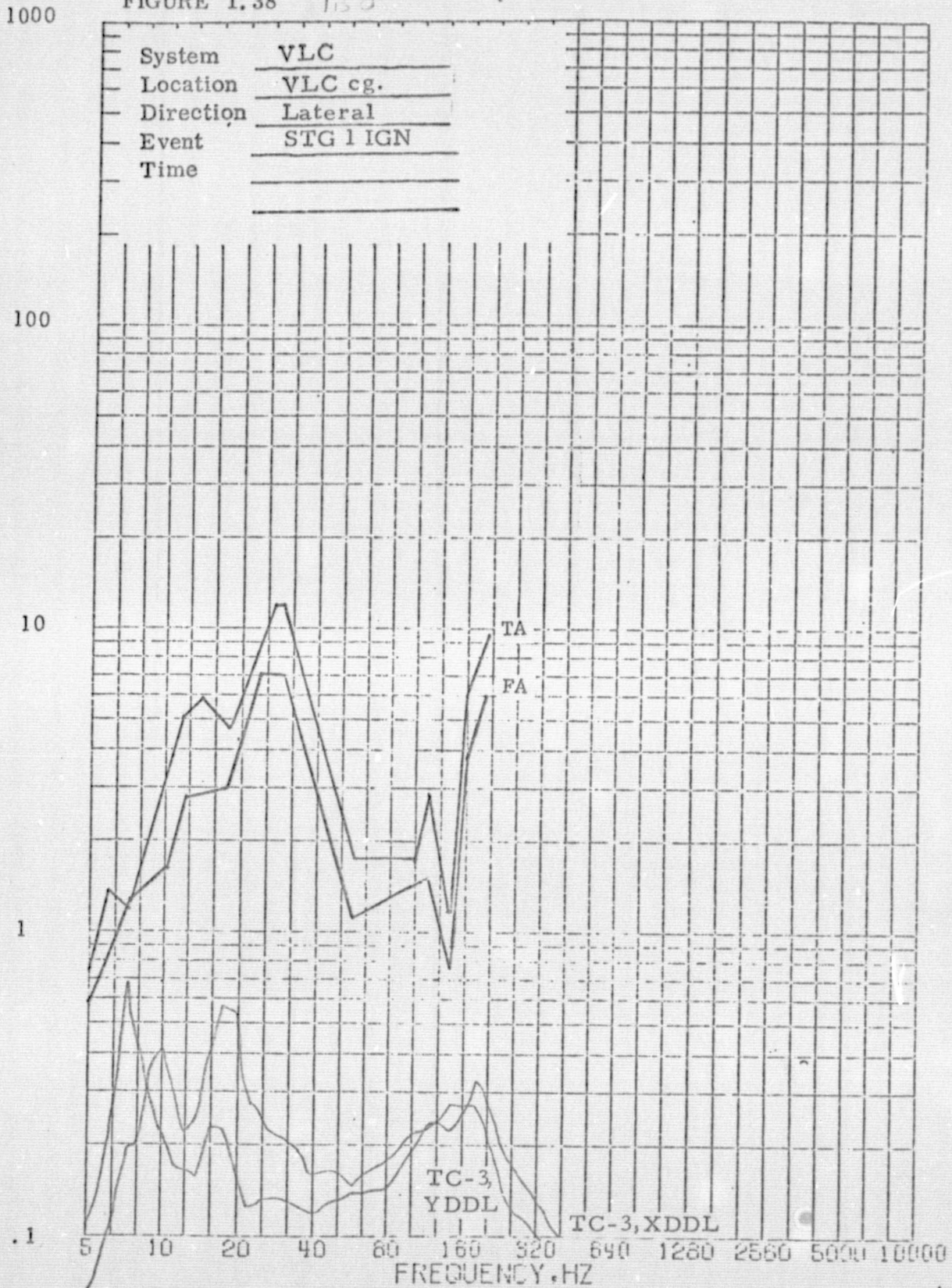
(3)

# SHOCK SPECTRUM

Q = 10

FIGURE 1.38

135





(3)

# SHOCK SPECTRUM Q = 10

FIGURE 1.39 1.39

1000

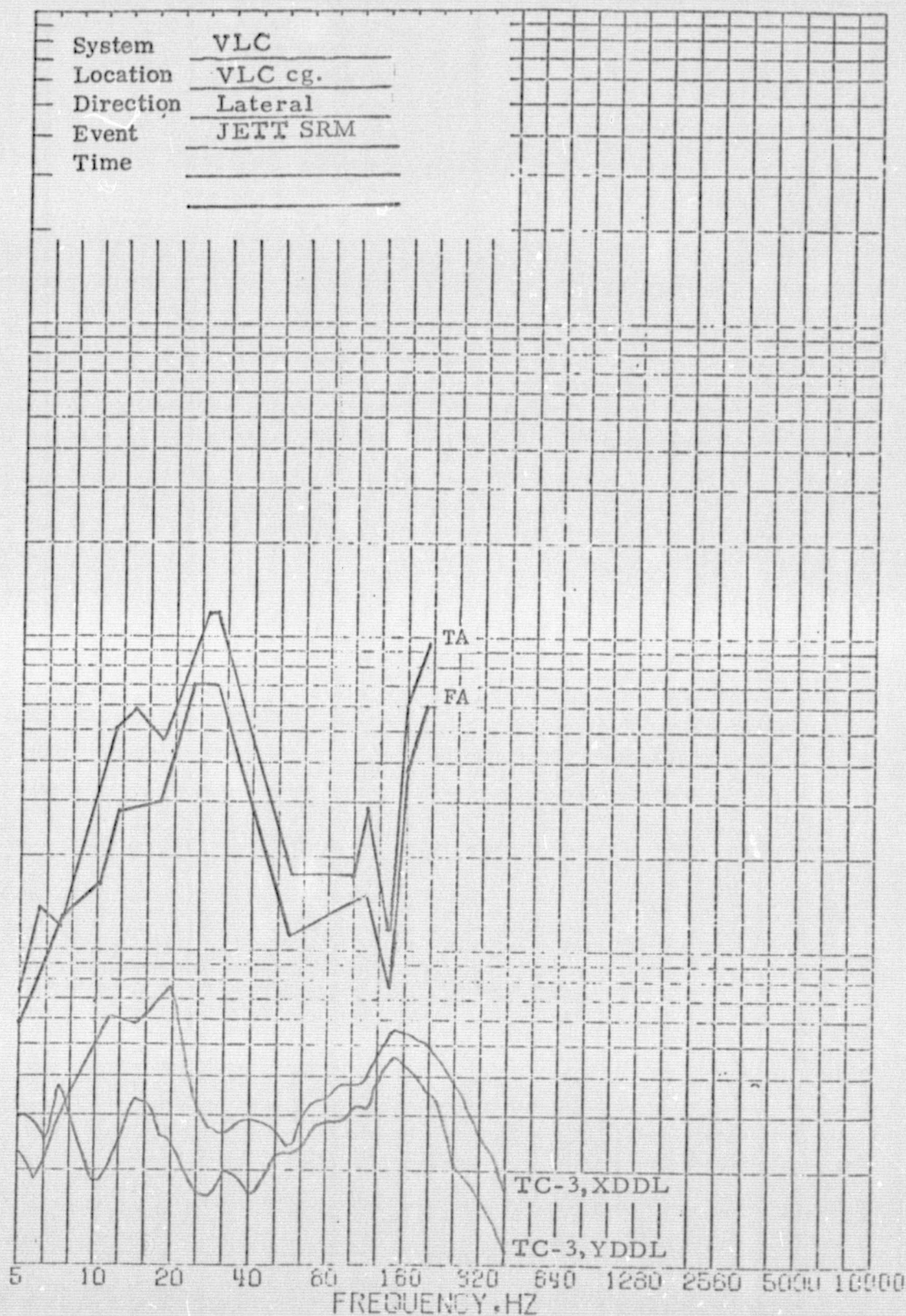
System	VLC
Location	VLC cg.
Direction	Lateral
Event	JETT SRM
Time	

100

10

1

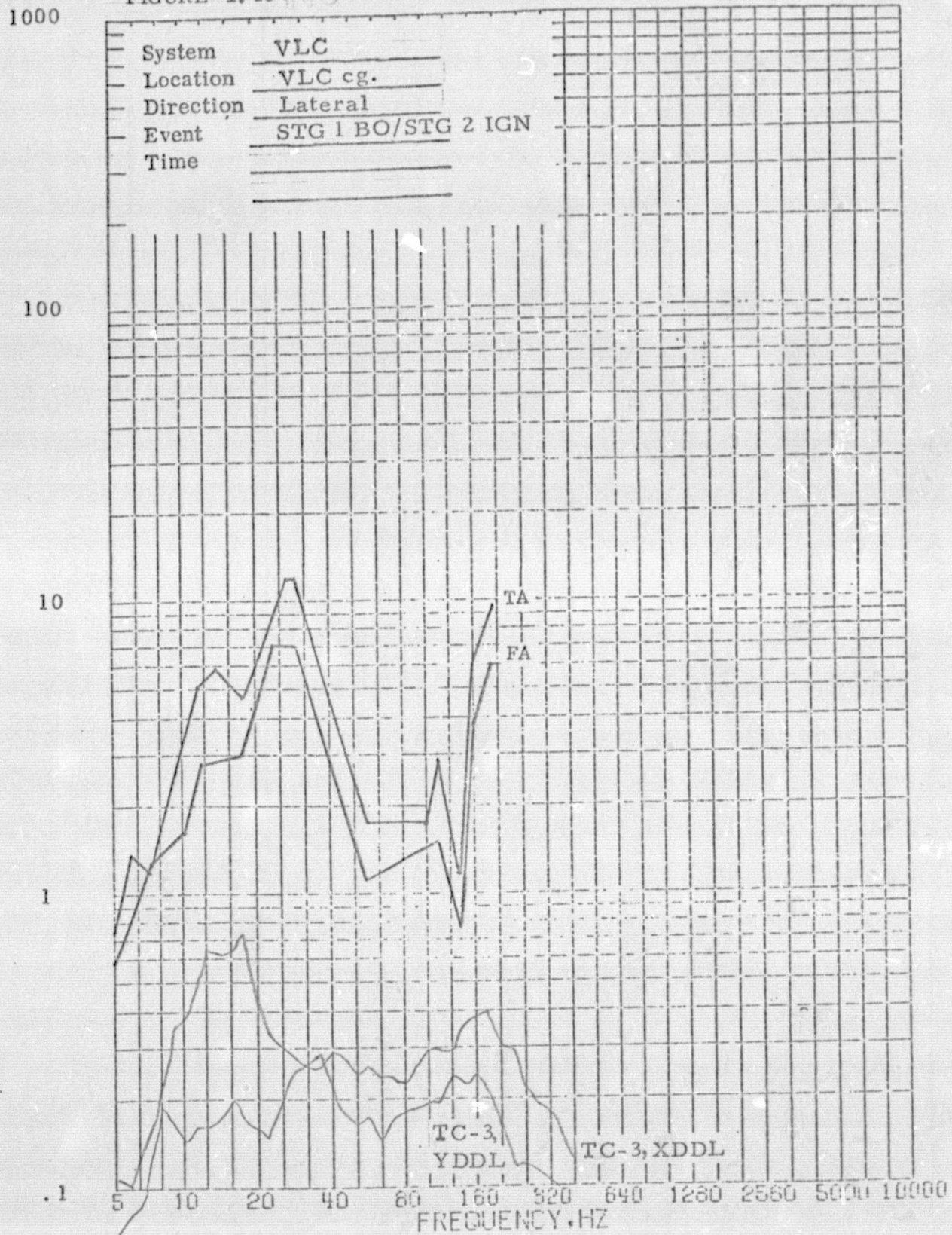
.1



3

# SHOCK SPECTRUM Q = 10

FIGURE 1.40

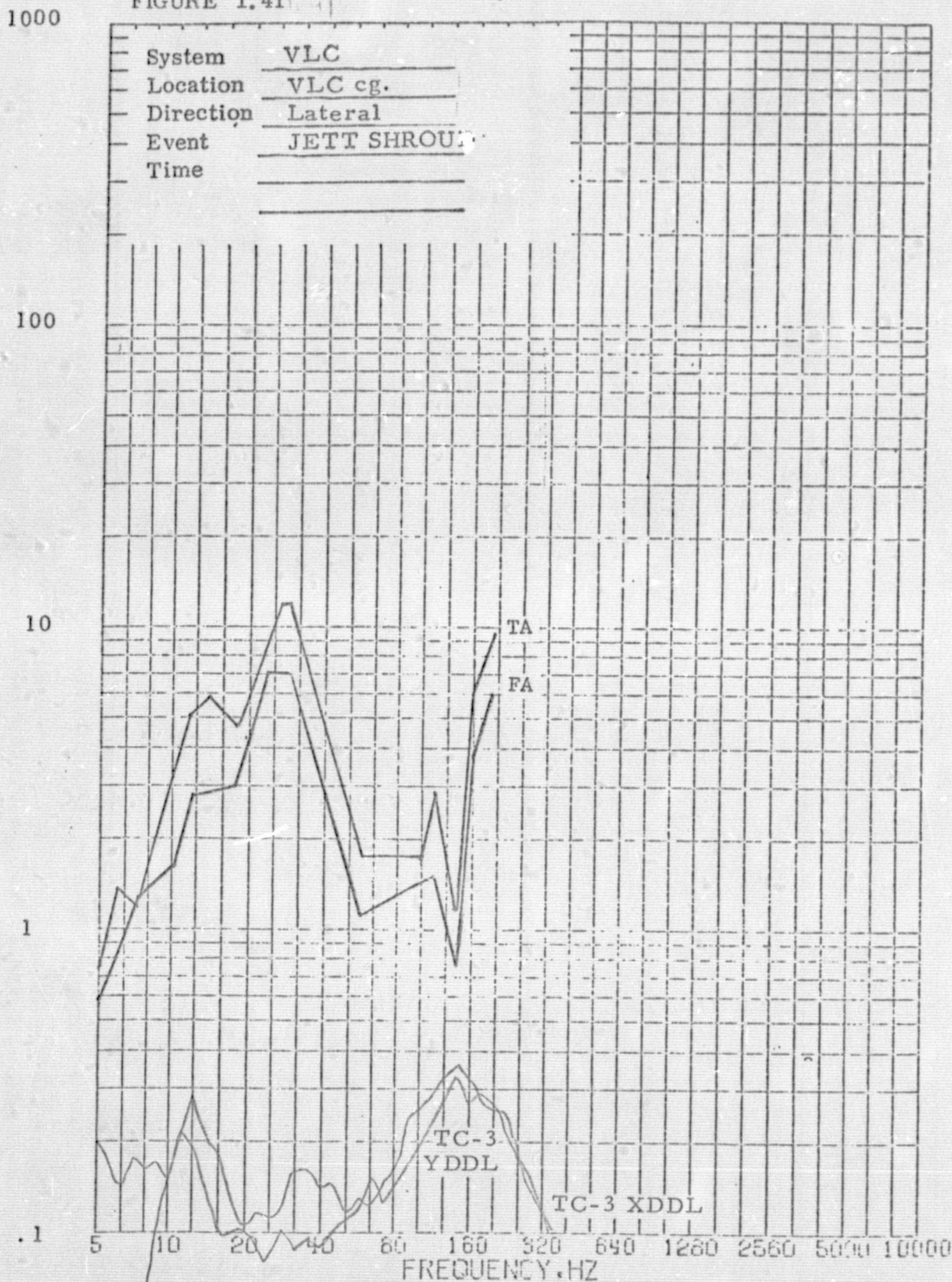




(3)

# SHOCK SPECTRUM Q = 10

FIGURE 1.41





3

# SHOCK SPECTRUM

Q = 10

FIGURE 1.421142

1000

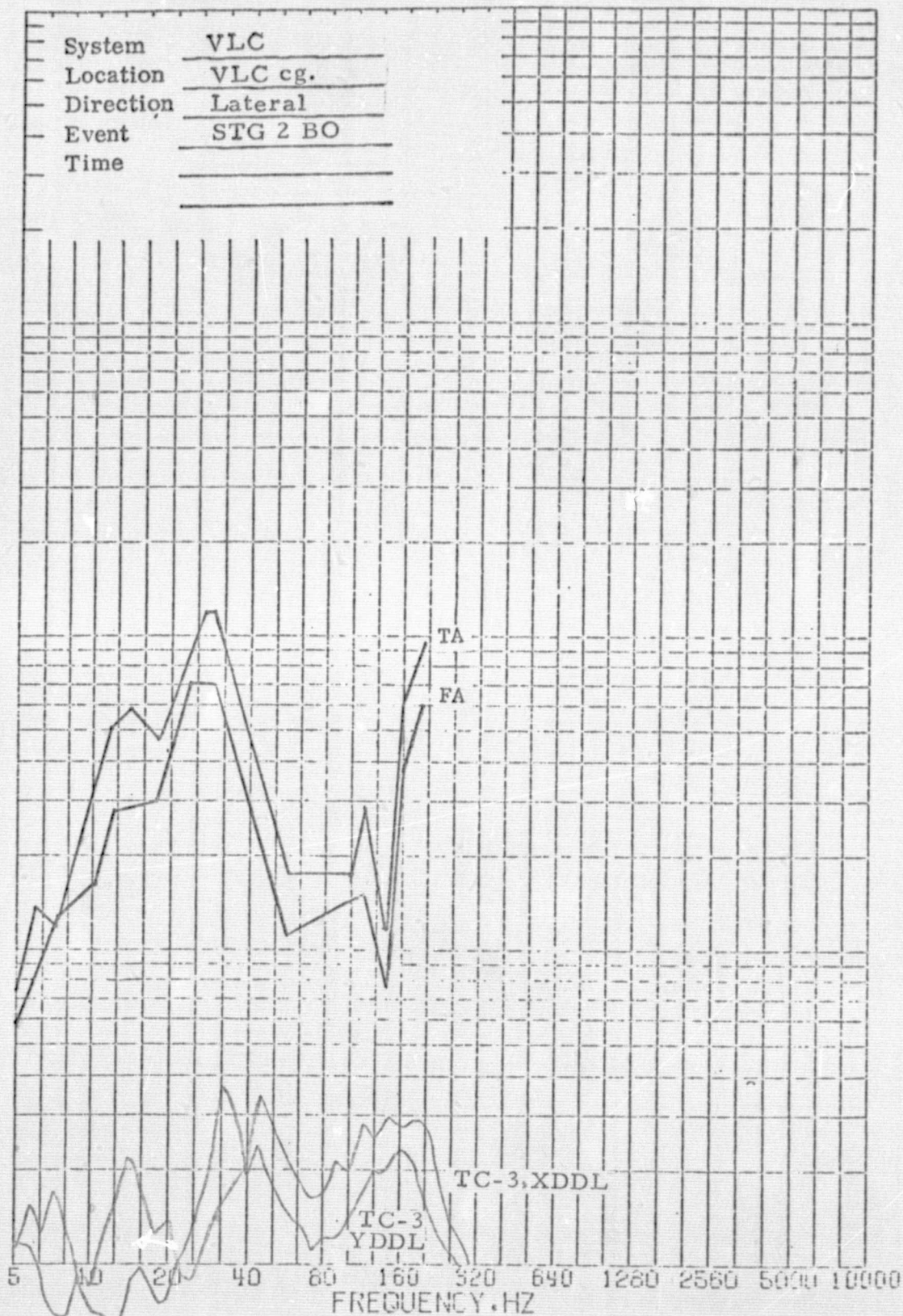
System	VLC
Location	VLC cg.
Direction	Lateral
Event	STG 2 BO
Time	

100

10

1

.1



(3)

# SHOCK SPECTRUM Q = 10

FIGURE 1.43

